Inquiry on Federal Water Policy
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INSTREAM RESOURCE VALUES
AND PROTECTION NEEDS
IN CANADA

by

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THE INQUIRY ON FEDERAL WATER POLICY

The Inquiry on Federal Water Policy was appointed by the federal Minister of the Environment in January of 1984 under the authority of the Canada Water Act. The members were Peter H. Pearse, chairman; Françoise Bertrand, member; and James W. MacLaren, member. The Inquiry was required by its terms of reference to review matters of water policy and management within federal jurisdiction and to make recommendations.

This document is one of a series of research papers commissioned by the Inquiry to advance its investigation. The views and conclusions expressed in the research papers are those of the authors. Copies of research papers and information on the series may be obtained by writing to the Enquiry Centre, Environment Canada, Ottawa, Ontario K1A 0H3.

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Abstract

Instream water resource uses are defined as the uses of water in place in lake, stream and estuary systems, as compared to offstream uses, taken out of the natural system. Instream uses include the environmental uses of providing habitat for fish and water-associated birds and mammals, as well as human uses that range from recreation and aesthetics enjoyment to pollution control and transportation. Conflicts are occurring over the use of water resources for different needs. Typically, the geographic scope of conflicts is confined within specific stream basins, but interbasin conflicts are also becoming common.

A major difficulty in addressing and settling conflicts is the determination of the value of the different uses. The valuation of instream water uses is rarely directly documented; rather, values generally are expressed in terms of the expenditures involved in making use of the water. The value of instream water quantity, therefore, has not been as adequately studied as has the value of water quality. Because of the scientifically documented and publicly accepted importance of water quality, large amounts of regulatory agency time and money have been allocated to controlling instream water quality. Instream water quantity control, however, has received much less attention such that the only water quantity documentation being done by the federal government is the water survey records compiled by Environment Canada, Inland Waters Directorate.

The lack of federal responsibility in instream water quantity control work likely has contributed to the geographically disjointed development of methodologies to quantify instream use value as a function of stream discharge. It is recommmended that most federal agencies presently involved in various aspects of instream water resource assessment and allocation relinquish their responsibilities in favour of the establishment of one agency which would be responsible for developing and administering regional, local and hierarchical strategies for applying specific instream flow assessment methodologies to specific situations.

Résumé

On peut diviser les utilisations de l'eau en deux grandes catégories: Les utilisations en milieu naturel (lacs, rivières, estuaires) et les utilisations à l'extérieur du milieu naturel. Les utilisations en milieu naturel comprennent les utilisations environnementales tel que la fourniture d'habitats pour le poisson et pour les oiseaux et mammifères vivant en étroite relation avec l'eau de même que les utilisations humaines qui s'étendent du plaisir tiré de l'aspect récréatif et esthétique de l'eau jusqu'à l'utilisation de cours d'eau à des fins de dilution et d'assimilation de la pollution de même qu'à des fins de navigation. Des conflits surviennent à propos de l'utilisation des ressources en eau lorsqu'on tente de satisfaire différents besoins. Généralement, l'étendue géographique de ces conflits est confinée à l'intérieur de bassins spécifiques mais les conflits entre bassins deviennent de plus en plus fréquents.

Un des problèmes majeurs lorsqu'on tente de régler ces conflits est la détermination de la valeur de chacune des utilisations. L'évaluation des utilisations de l'eau en milieu naturel est très rarement documentée de façon

directe. Les valeurs sont plutôt décrites en termes de dépenses effectuées lors de l'utilisation de l'eau. La valeur des volumes d'eau en milieu naturel n'a donc pas été aussi adéquatement étudiée que la valeur de la qualité de l'eau. Parce que l'importance de la qualité de l'eau a été documentée scientifiquement et acceptés publiquement, une grande partie des efforts et des fonds des agences de réglementations a été consacrée à la surveillance de la qualité des eaux en milieu naturel. La surveillance des volumes d'eau en milieu naturel a cependant reçu moins d'attention si bien que la seule documentation de nature quantitative assemblée par le gouvernement fédéral est celle des relevés hydrologiques compilés par la Direction générale des eaux intérieures d'Environnement Canada.

Le manque de responsabilité fédérale en matière de surveillance des volumes d'eau en milieu naturel a contribué au développement de plusieurs méthodologies régionales de quantification de la valeur des utilisations en fonction des débits. Il est recommandé que la plupart des agences fédérales présentement impliquées dans l'évaluation et l'allocation des ressources en eau en milieu naturel renoncent à leurs responsabilités en faveur de l'établissement d'une agence qui serait responsable du développement et de l'administration de stratégies régionales, locales et hiérarchiques visant à appliquer les méthodologies d'évaluation des débits en milieu naturel à des situations particulières.

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RECOMMENDATIONS[1]

1. Instream flow allocations should be established by inter-agency negotiation not by formal or legal review processes, because instream flow determination involves considerable technical judgment which cannot be legislated and which cannot withstand detailed cross-examination. Legal and administrative regulation should be used to confirm established instream flow allocations and to enable administrators to re-evaluate established allocations. There should be provisions in the legislation to make established flow allocation subject to renewal, and to enable citizens to press court claims for damage to instream resources caused by flow changes.

2. Legislation is required to provide for the drawing up of zoning and watershed plans for all areas in Canada where the federal government has jurisdiction related to instream flow allocation. Such classifications should provide areas for development and areas where instream flow resource preservation will have priority over development. There should be a national system of aquatic ecological reserves to protect and manage important instream fish and wildlife habitat areas established in legislation. Public hearings should be an appropriate method to establish and change such reserves.

3. Federal pollution control and habitat protection legislation provisions should be more consistently enforced in Canada.

4. Most federal Environmental Protection Service efforts now presently related to instream water quality management should be terminated and these departmental resources transferred to a water flow evaluation and management agency (see item 9). This would reduce the present large overlaps in federal-provincial and federal-territorial jurisdictions which are uneconomical and, in fact, counter-productive. Remaining federal water quality responsibilities should be transferred to the Department of Fisheries and Oceans.

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[1] These recommendations would apply to waters under exclusive federal jurisdiction, and to those where jurisdiction is shared with the provinces. For waters under exclusive provincial jurisdiction, similar water managment practices should be encouraged by the federal government.

5. Canada should develop a national program for determining instream flow needs. Such a program would set up a heirarchy of instream flow data determination methods for application in the country. Water management in Canada should be organized on a major watershed basis to reflect better resource allocation and local values.

6. Instream flow requirements should be subject to some year-to-year negotiation to raise or lower them to take advantage of water available in wet years and share shortfalls in dry years.

7. Instream resource management agencies should be required to respond to proposals for water resource development within 90 days of application.

8. All federal agencies having responsibilities for protection of instream resources should be decentralized to have more direct contact with local problems and people involved in them.

9. The present activities of the Inland Waters Directorate should be strengthened or a new agency created within Environment Canada to more fully manage water resources at the federal level. The agency would be responsible for developing the administrative mechanisms and for adjudicating conflicts among instream resource users and between instream and offstream users of water in areas under federal jurisdiction. The agency would also have members participate in provincial and territorial water use allocation processes to ensure that federal water and instream resource interests were taken into account. Additional resources for these activities could be obtained from making adjustments in federal water quality activities as outlined in item 4.

10. Until an official instream flow program is in place in Canada, for initial planning purposes, water management agencies should use the Montana Method[2] in setting instream flow regime limits. The regimes should be developed on systems where

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[2] For a full explanation of Montana and IFG methodologies, see secton IV, subsection 1.0.

offstream water resource projects are planned in the near future, or a requirement exists to improve the management of existing uses.

11. To check that planning flows are adequate for instream resources protection, it is recommended that a modified IFG[2] method be used, based on existing hydraulic cross-section information, flow records and biological criteria available for the system. Hydraulic information can be obtained from Water Survey of Canada gauging stations, historic flows from records taken at these gauges, and wetted area used as an approximate measure of fish habitat. Biological criteria from existing fish utilization index curves available in the Instream Flow Group publications can be used as a further guide for determining appropriate biological requirements if fish utilization information is not available from the stream for which a flow regime is being developed.[3]

12. The initial instream flow regime established for Canadian rivers and streams should be confirmed and refined by a site-specific field application of the full IFG-4 methodology where instream use values are rated to be high. The final flow figures developed by the methodology should be subject to modification as required based on expert judgment.[3]

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[3] These methodologies or a modification of them could be adopted as the official planning level instream flow setting mechanism if subsequent inter-agency negotiations determine that it is the most suitable.

I INTRODUCTION

Many land and water use planning groups have been established in Canada and the jargon of the disciplines involved appears throughout government planning exercises. Two of the major problems facing such planners is a way to assess the needs and values of instream resources[1]. Offstream water resource requirements and values can be quite accurately established and measured. Such measurements of instream resources cannot be made so easily.

Historic stream flow patterns have been changed as a result of man's manipulation and utilization of water resources. These actions have increased or reduced existing instream values, depending on the way the change from historic values was managed. The value of instream flows, as they apply to fish and wildlife habitat, recreation, and aesthetic values, is increasing as greater demands are placed on the instream water resource values to meet offstream needs of hydrolectric, industrial, irrigation and potable water supply projects. Water management programs, which attempt to balance instream and offstream uses logically, involve questions regarding the quantity and quality of water that should remain in the stream to protect existing instream uses. Physical habitat vital to biological resources must also be considered in these water management programs.

The main objective of this report, as outlined in the terms of reference for the work, was to identify the water requirements (quantitative and qualitative) of various instream uses[2], and their values; and to recommend appropriate means for their protection during other, sometimes conflicting, resource developments in drainage basins.

Specific sub-objectives of the report were to:

1. describe the full range of instream resource uses in Canada and their flow, depth and quality requirements;

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[1] The term "instream resources" in this paper includes those in lakes and estuaries.

[2] Hydroelectric uses were not considered in this paper to be instream water uses.

2. develop a methodology to assess the needs of instream resources;
3. suggest mechanisms to establish values of instream resources;
4. analyze current conflicts among instream uses, and between instream and other water and land uses, providing regional examples;
5. assess existing laws, regulations, and procedures for the protection of the aquatic environment, and recommend federal policy changes as appropriate to protect, restore and enhance instream resource values.

The report is organized into seven different sections as outlined in the Table of Contents. Conclusions and Recommendations were made as specific and clear as possible to enable direct use of them in future instream resource management programs.

II INSTREAM RESOURCES IN CANADA

1.0 BIOLOGICAL RESOURCES HABITAT

Instream biological resources include fish, and water-associated birds and wildlife, as well as marine invertebrate species and kelp that occur in estuaries. In some areas, important vegetation species are an additional instream biological resource. Stream flows and the biophysical conditions which are created by stream flows together determine quantity and quality of habitat available for the production of these instream resources and therefore directly determine the value of the resources. Biophysical conditions of natural river systems vary widely among river basins and within any one river basin. Very different conditions exist in river estuaries, where stream flow effects act together with oceanic processes. For instream biological resources, variations in biophysical conditions result in different species, different population levels and, ultimately, different resource values. The instream biophysical habitat conditions that produce valuable biological resources are summarized in the following sections.

1.1 Fish Resources

1.1.1 General Characteristics

Fish resources can be expected to occur in most freshwater environments in Canada. Most of the large lakes and rivers that do not freeze to the bottom in winter support populations of fish that make use of these waters throughout the year. The smaller streams and lakes that either freeze to the bottom in winter or dry up in late summer generally contain habitat for migratory fishes on a seasonal basis.

Several freshwater fish species spend much of their adult life in the sea or in large lakes, and use rivers and lakes either for spawning (with the young fish returning to the lake or sea, where they grow to maturity), or as migration routes between lakes or to the sea. The major fish species can be found in both lake and river habitats.

Many of the small lakes and streams dry up in late summer or freeze to the bottom in winter. Fish that use these systems seasonally must move to well-oxygenated water such as lakes or deep pools in rivers to overwinter. The availability and accessibility of such overwintering areas are limiting factors in the distribution of some species in these systems. In northern Canada, the relatively short open water season, low productivity and cold water temperatures result in slow growth rates for most fish. Fish in the more southern drainages are faster-growing by comparison. The Mackenzie, Churchill and Nelson Rivers provide more favourable habitat for fish than their northern tributaries because they are fed by warmer waters located in temperate areas of Canada. Their large drainage areas mean that higher amounts of nutrients are fed into the rivers which, combined with the water temperature, increase productivity. The Mackenzie River moderates climate within the Mackenzie Valley and indirectly affects the lower reaches of tributary streams and rivers.

1.1.2 Fish Species and Ecology

Scott and Crossman (1973) describe the biology and distribution of Canada's fishes, which number over 180 species. The distribution of these species by province and by watershed is summarized as follows:

Numbers by Geographic Area

Insular Newfoundland	20	Manitoba	79
Labrador (Nfld.)	21	Saskatchewan	60
Nova Scotia	34	Alberta	51
Prince Edward Island	19	British Columbia	71
New Brunswick	48	Northwest Territories	41
Quebec	105	Yukon Territory	31
Ontario	132	Alaska	40

Numbers by Drainage Basin

Atlantic	142
Hudson Bay	94
Arctic	56
Pacific	67
Gulf of Mexico	27

The majority of fishes spawn during either spring or fall. For spring spawners, the egg incubation period is short, and the young hatch in a matter of weeks. The eggs of fall spawners remain in the gravel and develop slowly over the winter. The young hatch in the spring. Survival of the fall spawners requires that spawning occur in the habitats where flowing water will be present throughout the winter.

In northern regions of Canada, growth rates of fishes tend to be slow. As a result, sexual maturity occurs at later ages than in more southern populations. Another consequence of the slow growth is that many individual fish in northern populations do not spawn every year. The populations of large individual fish, often considered to be characteristic of northern waters, result from many years of slow growth. Changes in lake levels and stream discharges in systems used by northern fish species, in conjunction with the slow growth rates and low rates of reproduction, can result in a significant reduction in the population sizes.

1.1.3 Fish Habitat and its Utilization

The physical characteristics of lakes and streams vary greatly, resulting in diverse aquatic ecosystems and fish habitat. This section summarizes the characteristics of various lakes, rivers and streams, and outlines the general freshwater ecosystem features that are necessary for fish habitat.

1.1.3.1 Lake Types

Lake types range from small, shallow, snowmelt lakes to large, deep lakes that feed the larger rivers. In northern areas, up to 3 m of ice may be expected on lakes in late winter. This depth (3 m) can be used as the criterion to distinguish between shallow and deep lakes.

1. Shallow Lakes - these are less than 3 m deep, have ice to the bottom in winter, and are probably of limited importance to fish.

2. Deep Lakes - these lakes have depths greater than 3 m, and in many parts of the far north, they are the only suitable overwintering and spawning areas available for fish.

In the southern regions, lakes are described by more conventional biophysical classifications of oligotrophic, mesotrophic and eutrophic groups, and special types.

1. Oligotrophic Lakes - these lakes are generally deep and steep-sided and have limited shallow areas and low nutrient supply. These lakes are considered to be relatively unproductive.

2. Mesotrophic Lakes - these lakes have large shallow areas, more nutrients, perhaps warmer water, and are generally more productive.

3. Eutrophic Lakes - these lakes are shallow, but have a high nutrient content, and are more productive for fish. They may have a summer stagnation period, which could exclude cold water fish from utilizing them.

4. Special Lake Types - in addition to the above general classification, some lakes may be classified as one of the following:

    a) Dystrophic Lakes - brown water, humid bog lakes that have low pH and peat-filled margins.

    a) Impoundments - artificial lakes characterized by artificial level fluctuations, and perhaps unstable shorelines.

1.1.3.2 River and Stream Types

River and stream types vary greatly, ranging from small, snowmelt drainage channels, abundant in the Arctic tundra, to the large St. Lawrence, Mackenzie, Churchill, Nelson and Fraser Rivers. They are classified according to their seasonal discharge pattern, which is particularly useful in assessing their potential as fish habitat.

1. Perennial Streams and Rivers - these are usually the larger systems that have flowing water at all times. As such, they provide fish habitat all year round and may be important as migration routes, overwintering areas, spawning grounds or rearing areas. Highly productive estuary habitat is often associated with major coastal systems. Some perennial streams are very small systems, but they have winter-long flows provided by springs, and therefore contain important overwintering habitat for fish.

2. Summer Streams - these are streams of moderate size characterized by high discharge during spring runoff, but low late summer flows. These streams may freeze to the bottom in winter. Their use by fish is limited to the flowing water period, but they may be important as spawning grounds for spring spawners or as feeding areas during the summer.

3. Ephemeral Streams - these streams may have high spring discharges, but are dry by late summer. They may be in the headwater regions of drainages or small tributaries to lakes and rivers. Some ephemeral streams near lakes and rivers may be utilized by fish for short periods for feeding or spawning.

1.1.3.3 Aquatic Ecosystems and Lower Trophic Levels

Freshwater systems contain complex aquatic communities consisting of several interdependent food chain levels: macronutrients, vascular plants and phytoplankton, zooplankton, aquatic invertebrates and fish. The composition and size of these communities reflect the general physical and chemical conditions of the aquatic environment. The wide range of climatic conditions prevailing in Canada from the Arctic conditions in the north, to the temperate conditions in the south, has given rise to an equally wide range of aquatic and freshwater habitats for aquatic life. Adaptation to these conditions has led to distribution gradients from north to south for some aquatic species, and from south to north for others. Some species are very restricted in their range, whereas others are widely distributed, possibly as a result of a greater tolerance to extremes in environmental conditions, or perhaps as a result of less competition from other species.

The more northern drainages having extreme climate and fewer types of habitat for aquatic organisms support fewer species; however, large numbers of individuals of some species may occur. The abundance and diversity of benthic invertebrates decline with increasing latitude and the freshwater systems of temperate Canada have more complex food webs than those in the high Arctic, where most lakes and even the large rivers freeze to the bottom in winter, and may remain frozen from November to June. The nutrient systems in the Arctic therefore tend to be based on detrital sources. The streams and rivers, therefore, support mainly invertebrate species such as midges and segmented worms that can utilize detritus and can live in the stream bottom substrate, and thereby escape dislocation by ice or dessication in the absence of free-flowing water. Other invertebrates such as mayflies, caddisflies and stoneflies, which live mainly on the surface of the substrate, are more abundant in the more southern areas where icing and dessication are less severe. Turbid, silt-laden rivers support less abundant and less diversified invertebrate fauna than systems with low concentrations of suspended sediment (Brunskill et al. 1973).

The southern drainages, having warmer water and less severe winter conditions, generally provide more habitat types to support a greater number of species. These species, living in a less stressed situation, generally have wider tolerances to environmental change than those in northern drainages. In most cases, escape from winter ice is not a problem, and at least for the larger systems, the full range of habitats can be utilized throughout the year.

1.1.4 Utilization of Habitat by Fish in Canada

Fish make use mainly of large, deep lakes and streams that flow throughout the summer months. Overwintering habitat is available only in waterbodies that do not freeze to the bottom in winter. Many lakes and streams are shallow, and freeze to the bottom in winter. Large, deep lakes and deep pools in the larger streams and rivers all provide overwintering habitat. Most species also use lakes year-round, using spawning and rearing habitat in lake shallows. Where there are tributaries or lake outlet streams of sufficient size, they will also move out of the lake in summer and use feeding and rearing habitat in the streams. Some spring spawning species move from lakes in spring to gravel and cobble spawning areas in the tributaries. The eggs hatch and the fry use rearing habitat in the streams before moving down to the lake before the fall.

Rivers and streams that run to the sea are also used by anadromous species which migrate up from the sea to spawn, and by catadromous fish (the Atlantic eel, Anguilla rostrata) which live in rivers and migrate to the ocean to spawn. Pacific salmon spawn in rivers and tributaries, and then die. Atlantic salmon use much the same habitat, but do not usually die after spawning. Trout and char typically use streams and rivers having lakes where they can overwinter after spawning. After spring break-up, the adults return to the sea. Juveniles of most species use rearing and feeding habitat in the lake or river, and move downstream to the sea after one to three years. In lakes without connections to the sea, landlocked populations of anadromous fish may exist. Landlocked fish may spend their entire lives in the lake, and are characteristically smaller than the anadromous forms.

As indicated above, different conditions of geology, topography and climate create particular river basin characteristics and instream biophysical conditions, and each fish species is adapted to a certain regime and biophysical habitat parameters and therefore, within its natural range, the species will be present in greatest abundance where these conditions approach optimum levels, and will be rare or absent in areas where biophysical conditions lie outside the range of suitable habitat parameters. Every species-specific parameter is directly or indirectly affected by instream flow conditions.

Obvious differences in habitat requirements exist among and within taxonomic groups. For example, habitat conditions for salmon and trout are substantially different than habitat conditions for perch and walleye. Salmonid habitat, in general, includes moderate flow velocities, grannular substrate, clear cool water and a regular alternation between open, shallow riffle areas and overhung, deep pool sections. These conditions contrast with the habitat used by members of the perch family which, while capable of making use of some of the habitat conditions required by salmonids, can also tolerate warm temperatures, moderate to high turbidity, a greater proportion of fine sediments in spawning substrates and a high proportion of lakes or instream habitat having very low velocities.

Some of the variation that can exist in habitat conditions preferred by the species within a family can be seen in the salmonids. Specific data on spawning habitat requirements have been compiled for several salmonid species.

Hamilton (1978) compared depth and velocity criteria for spawning by five species of salmon. Sockeye salmon were reported to have a wide depth preference range between 0.10 and 0.90 m and a fairly narrow velocity preference range of 0.30 to 0.80 $m.s^{-1}$ (Stober and Graybill 1974). By comparison, chinook salmon generally prefer depths greater then 0.25 m (Thompson 1972; Chambers et al. 1955) and pink salmon preferred velocities between 0.20 and 1.00 $m.s^{-1}$ (Collings 1974).

In addition to these specific habitat needs, there are other differences in the habitat requirements for these species. Chum salmon prefer unobstructed migration passages, make substantial use of spawning habitat in small river channels, and generally do not require freshwater rearing habitat. Sockeye salmon can tolerate moderate migration passage obstacles within the limit of their leaping capability. Sockeye spawning habitat is typically in streams that have lakes in their watercourses, and they require rearing habitat in these lakes. Chinook salmon can tolerate low to moderate difficulty in migration passage and they spawn in open streams and rivers. They require rearing habitat and productive areas of streams and rivers for as much as a year prior to their migration to sea.

Because instream flows determine biophysical conditions for fish habitat and because each species has particular habitat requirements, changes in instream flow will affect different species in different ways. Figure II-1 indicates the effect of a stream diversion on three hypothetical species inhabiting different areas along the length of the stream. The relationships between fish species and instream flows are complex and it is the quantification of these relationships that presents considerable difficulty in developing instream flow allocation programs (see Appendix I).

1.2 Water-Associated Birds and Wildlife

Water is an essential component of the habitat used by migratory birds and wildlife. Among the many bird and wildlife species that use aquatic habitat, there exists a great diversity in habitat requirements. A good description of the bird and wildlife habitat needs was prepared by Environment Canada (1976). The following is extracted from this publication.

Habitat for nesting and feeding as well as for resting during migration, is necessarily near open water to enable the adults and the young to reach water easily, and it must contain a suitable vegetation community to provide cover protection for young-of-the-year, and for adults that because of moulting cannot fly well or at all. Plants that provide protective habitat include certain sedge, grass, rush, alder and other tree species. Protective habitat is particularly good when these species are present in the early stages of succession that occur under specific water conditions.

Adult birds feed on plant and aquatic animal food sources and the young consume substantial quantities of aquatic insects and insect larvae. Feeding habitat, therefore, is provided by specific marsh, lake and stream conditions, particularly water quantity and quality characteristics that produce sufficient quantities of these food supplies.

Aquatic mammals include primarily beaver, muskrat and otter. Mink and raccoon also require aquatic habitat, but not as extensively as beaver, muskrat and otter.

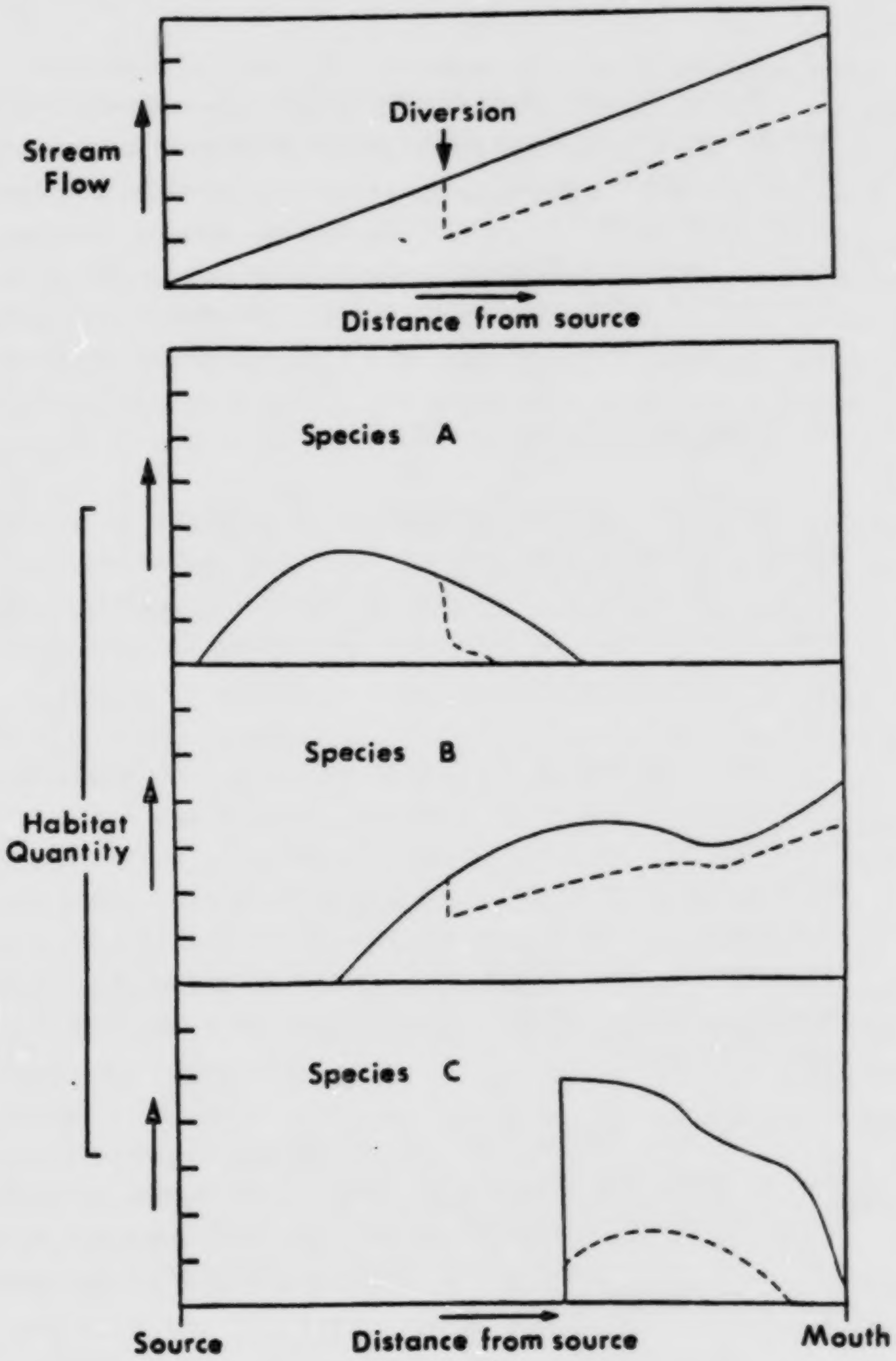

FIGURE II-1
Effect of a hypothetical stream flow diversion on three arbitrary species.

——— Pre-diversion condition
- - - - - - Post-diversion condition

The beaver is highly dependent on water quantity characteristics. Flowing water is required for dam building. Depths at greater than 1.1 m are needed around the lodge and large open areas containing appropriate plant species for food are required. The food plants include certain aquatic species as well as trembling aspen, large tooth aspen and willow.

The muskrat also depends on habitat containing appropriate water depth. Shallow areas produce the required alternation between open areas and areas containing immerged aquatic vegetation and other water-associated plants. The muskrat eats aquatic grass and sedge as well as the flower and fruit of other aquatic species. While the required plant species are abundant in shallow areas having organic sediments, depths must exceed 60-90 cm to maximize the survival rate in the winter.

The otter is best described as an "amphibious" mammal (Bamfield 1974); it is highly adapted to swimming on and under water and is very capable of overland travel. The otter makes its nest on stream or lake banks or in marshes and spends much of its foraging time at the water's edge. Most of its food is obtained by capturing it under the water. Its diet consists primarily of fish, aquatic invertebrates and amphibians.

The mink and the raccoon also inhabit marsh and streamside areas. Mink dens often are located along streams banks. A primary food for mink is fish. The raccoon, while being aquatic-oriented, is much more tolerant of artificial habitat such as agricultural and residential land. Its food sources are highly varied. However, its natural feeding habitat most frequently includes swamp, lakeshore and stream bank areas where it can capture small fish, crayfish and other aquatic invertebrates.

The importance of instream water resources to terrestrial furbearers, small mammals, ungulates and other mammals is related largely to the use by these animals of riparian and wetland habitat. River floodplains, sloughs and marshes are characterized by seasonal and annual variations in water level and undergo important inundation events that, among other effects, distribute nutrient-rich sediments to the riparian soil and recharge the water table. The annual growth of vegetation, invertebrates and small vertebrates collectively provide important components of the mammalian habitat needs.

1.3 Water-Associated Vegetation

A number of plant species requiring aquatic or riparian habitat are of particular value to Canadians. In northern Ontario, wild rice is a highly valued species that grows in lake shallows and its harvesting is an important part of traditional lifestyle. In eastern Canada, the floodplain areas of certain streams provide the conditions necessary for the growth of a particular fern species, the shoots of which are picked and marketed as fiddleheads. Throughout Canada, riparian vegetation often includes various bushes that produce edible berries which, while not of commercial value, are important to subsistence food resources and form part of the enjoyment experienced by recreational users of riparian habitat.

Wild rice has been the focus of considerable attention and concern. At the hearings of the Hartt Commission Inquiry into the environment of northern Ontario (Royal Commission on the Northern Environment 1978 Issues Report, p. 103-107), descriptions were given of the traditional, cultural and social significance ascribed by native Indians to the wild rice harvest. Conflicts exist between native and non-native northerners over the right to harvest wild rice, and a substantial amount of research, as well as unscientific experimentation, has occurred in relation to various ways to grow and mechanically harvest wild rice. Statements were also submitted that indicated that wild rice is sensitive to water levels and that the size of the crop each year depends on the magnitude of water level fluctuations.

2.0 BIOLOGICAL AND SOCIO-ECONOMIC RESOURCE USE ACTVITIES

2.1 Fisheries

Freshwater and marine fish stocks are harvested by commercial, native and sport fisheries. Freshwater fisheries are entirely dependent on the preservation of freshwater habitat conditions necessary for the production of the fishery stock. The marine fishery also depends in part upon the preservation of freshwater conditions for the production of anadromous species. Commercial fisheries are considered to be of the greatest value because of their importance to local, regional and national economies. In 1974, commercial fisheries employed approximately 80,000 people (Environment Canada 1976). Sport fisheries are also very valuable, not only because of the revenue generated in the equipment supply and tourism industries, but also because of the high intangible values of recreation, leisure and aesthetic enjoyment associated with sport fishing. Domestic fisheries, which are mainly food fisheries practiced by the native Indian and Inuit people, are important in terms of their cultural heritage, the contribution of the fishery harvest to native food supplies and the past and present conflicts over legal fishing rights. The following sections describe some of the values of these three fisheries.

Commercial Fisheries

The status and outlook for Canada's commercial fisheries were described by Mitchell (1980) who noted the distinctions among the Atlantic, Pacific and inland fisheries. The inland fisheries rely entirely on species captured in freshwater. The species fished are listed in Table II-1. For the years 1976, 1977 and 1978, the total production in the inland fisheries was 44,842 metric tonnes. Distribution among the various provinces and territories of the average catch for the same three years is shown in Figure II-2.

While production varies from year to year, with recent lows and highs being 39,667 tonnes in 1976 and approximately 55,000 tonnes in 1969, Canada's inland production has remained stable relative to the greater fluctuations evident in the Atlantic and the Pacific fisheries (Figure II-3).

Table II-1 Inland Fisheries catches (metric tonnes) by species, 1976, 1977 and 1978 (from Mitchell 1980).

Species	1976	1977	1978	Mean
smelt	8,276	10,680	12,399	10,452
whitefish	7,852	9,214	8,550	8,539
perch	3,322	4,794	4,936	4,351
yellow pickerel	4,572	5,697	4,339	4,869
pike	3,383	3,888	3,920	3,730
tullibee	2,073	1,923	1,972	1,989
sauger	1,689	1,595	1,335	1,540
trout	840	968	693	834
carp	293	911	711	638
other	7,367	7,619	8,716	7,901
Total	39,667	47,289	47,571	44,842

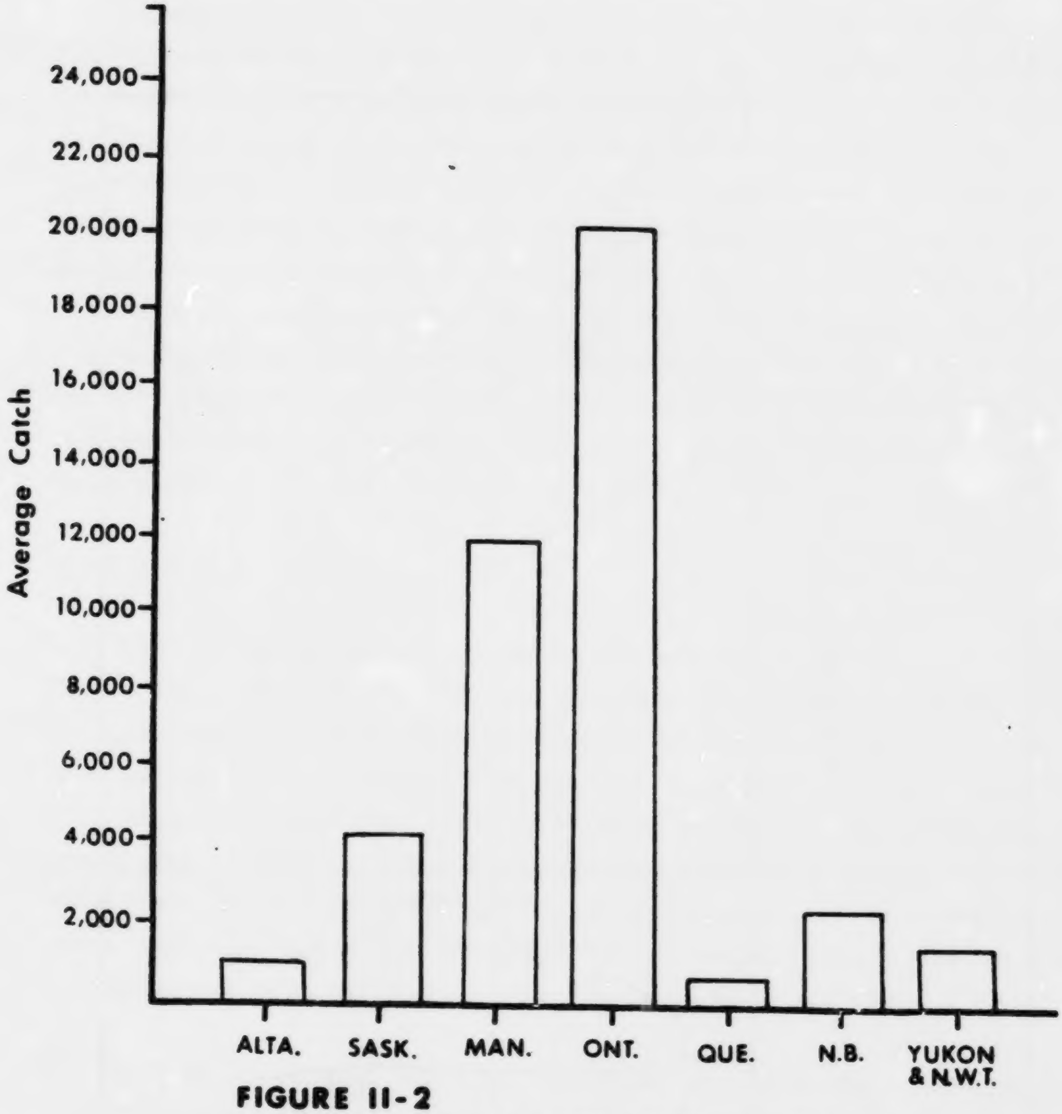

FIGURE II-2

Average catches for 1976, 1977 and 1978. (From data compiled by Mitchell 1980)

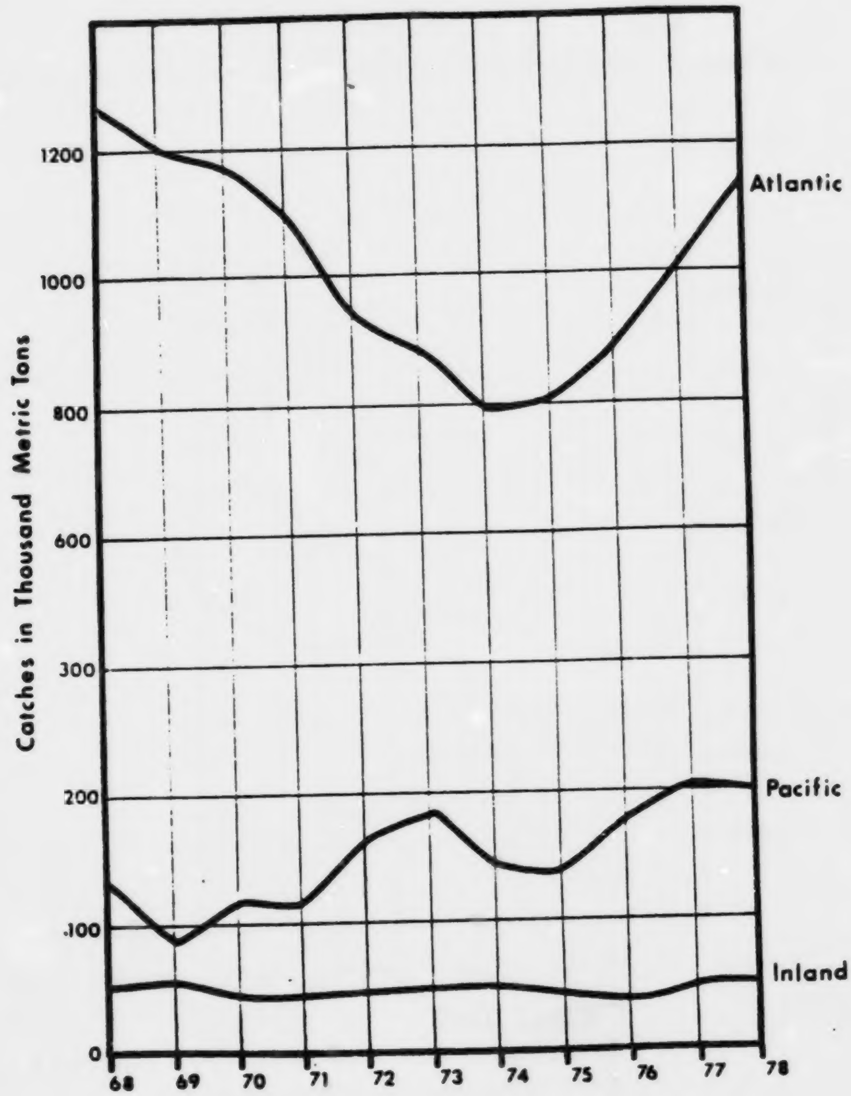

FIGURE II-3

Catches in Atlantic, Pacific and inland fisheries 1968 to 1978.
(From Mitchell, 1980)

In addition to the catches taken in the inland fisheries, the Atlantic and Pacific fisheries catch anadromous species that are dependent on freshwater resources and habitat conditions. This is particularly evident in the Pacific fishery in which salmon catches have made up 28.5% of the total sea fishery catch. Other anadromous fish captured in the Pacific fishery include several members of the smelt family, most notably eulachon. In the Atlantic fishery, anadromous fish species harvested commercially include Atlantic salmon, shad and alewife. In the Arctic, in the western Hudson Bay area, there are commercial fisheries for anadromous Arctic char. Anadromous whitefish species were harvested in the past for short-lived commercial fisheries in the Mackenzie Delta area. In the Yukon, commercial fisheries for chinook and chum salmon operate on the Yukon River, near Dawson City.

Sport Fishing

Sport fishing for species that use freshwater habitat occurs throughout inland Canada and, in the case of anadromous species, in the nearshore areas of the east and west coast. The most highly-prized sport fish species include chinook salmon and steelhead trout in western British Columbia, kokanee (the non-anadromous form of sockeye salmon), rainbow trout, brown trout, brook trout, lake trout, walleye, sauger, pike, perch, Arctic grayling, bass species, whitefish species and lake cisco in western and central Canada, and Atlantic salmon, anadromous hake, tommy cod and smelt, brook trout and pike in eastern Canada. In northern Canada, the key sports species are lake trout, Arctic char, Arctic grayling, walleye and pike.

In 1980, more than 6,000,000 Canadians and more than 1,000,000 non-Canadians fished for recreational purposes (Tuomi 1982). In 1975, when angler effort was 74.8 million angler days (Table II-2), the highest effort occurred between April and September, when 56% of the annual angling effort took place. Of the total amount of nearly 229,000,000 fish caught in 1976, over half was made up of catches of four species: yellow perch, brook trout, walleye and pike (Table II-3). In 1980, anglers' catches contributed to 45,200 metric tonnes of domestic food which represents approximately 40% of the total domestic consumption of fin fish taken in Canadian sport and commercial fisheries (Tuomi 1982).

Table II-2 Angler effort (1975) by season (in '000 angler days) (Source: Hatfield 1978).

	Resident	Non-Resident Canadian	Other	Total
January-March	4,809.9	27.1	119.9	4,956.9
April-June	20,556.3	342.9	2,642.0	23,541.2
July-September	37,020.9	750.2	4,303.4	42,074.5
October-December	3,913.2	41.6	233.8	4,188.6
Canada Total	66,300.3	1,161.8	7,229.1	74,761.2

Table II-3 Number of fish caught and retained by species (in '000) in the sport fishery (Source: Hatfield 1978).

	Fish Species	Resident	All Non-Residents	Total
1.	Yellow Perch	37,413	5,898	43,311
2.	Brook Trout	37,628	801	38,429
3.	Walleye	14,664	6,797	21,461
4.	Pike	12,305	3,990	16,295
5.	Catfish	7,924	143	8,067
6.	Smallmouth bass	6,366	1,489	7,855
7.	Rainbow trout	7,012	729	7,741
8.	Atlantic tomcod	6,309	[a]	6,309
9.	Lake trout	5,638	648	6,286
10.	Atlantic cod	4,433	[a]	4,433
11.	Bass (unspecified)	4,068	289	4,357
12.	Largemouth bass	3,353	665	4,018
13.	Trout (unspecified)	3,658	79	3,737
14.	Perch (unspecified)	3,013	170	3,183
15.	Whitefish (unspecified)	1,967	222	2,189
16.	Atlantic mackerel[b]	1,763	[a]	1,763
17.	Others[c]	41,582	7,654	49,236
	Canada Total	199,096	29,574	228,670

[a] Numbers caught and retained are not considered to be statistically reliable.

[b] Mackerel is not a freshwater species, but is included here because it is caught in the sport fishery more than any other marine species (e.g. salmon and tuna). The next most commonly caught species was coho salmon at 1,221,000 fish.

[c] Although retention of over 18 million rainbow smelt (Osmerus mordax) is included, the methods of catch and the size of the species are such that a relative comparison, for purposes of this table, is not meaningful.

The approximate freshwater sport fishery values for 1980 are presented in Figure II-4. These values which represent the "economic activity generated by sport fisheries" (Tuomi 1982) amount to a total of approximately 1.75 billion dollars. This includes the 0.21 billion dollar value of the British Columbia tidal waters sport fishery. Of the total 1.75 billion dollars, approximately 1.05 billion dollars was generated by the expenditures on food, lodging, travel costs, boat operation and fishing supplies, and 0.70 billion dollars included boat and motor purchases and vehicle, land and cottage expenditures (Environment Canada 1985). United States visitors spent approximately 300 million dollars on sports fishing-related services, equipment and supplies in Canada (Environment Canada 1985).

Sport fishing is a major factor in Canadian quality of living. Urban and rural residents alike receive substantial recreational satisfaction from fishing or from being provided the opportunity to fish. Canadians express an appreciation for the biology of fishes and for the high quality habitat that fishes require. This strong appreciation for fish and fishing is always evident when controversy develops between water use for fish resources and for any other major instream or out of stream use for the water.

Domestic Fishing

Information on domestic fisheries in Canada is sparse and often unreliable. Native fisheries take place in British Columbia, the three prairie provinces, the Northwest Territories, Ontario, Quebec, Labrador, Nova Scotia, New Brunswick and the Yukon. Pertinent information available for the Northwest Territories and British Columbia is summarized as follows:

Northwest Territories:

It is very difficult to obtain accurate estimates of domestic fish harvest in the Northwest Territories. Although the domestic harvest has decreased in the last decade because of a decreasing number of dogs and therefore a reduced need for dog

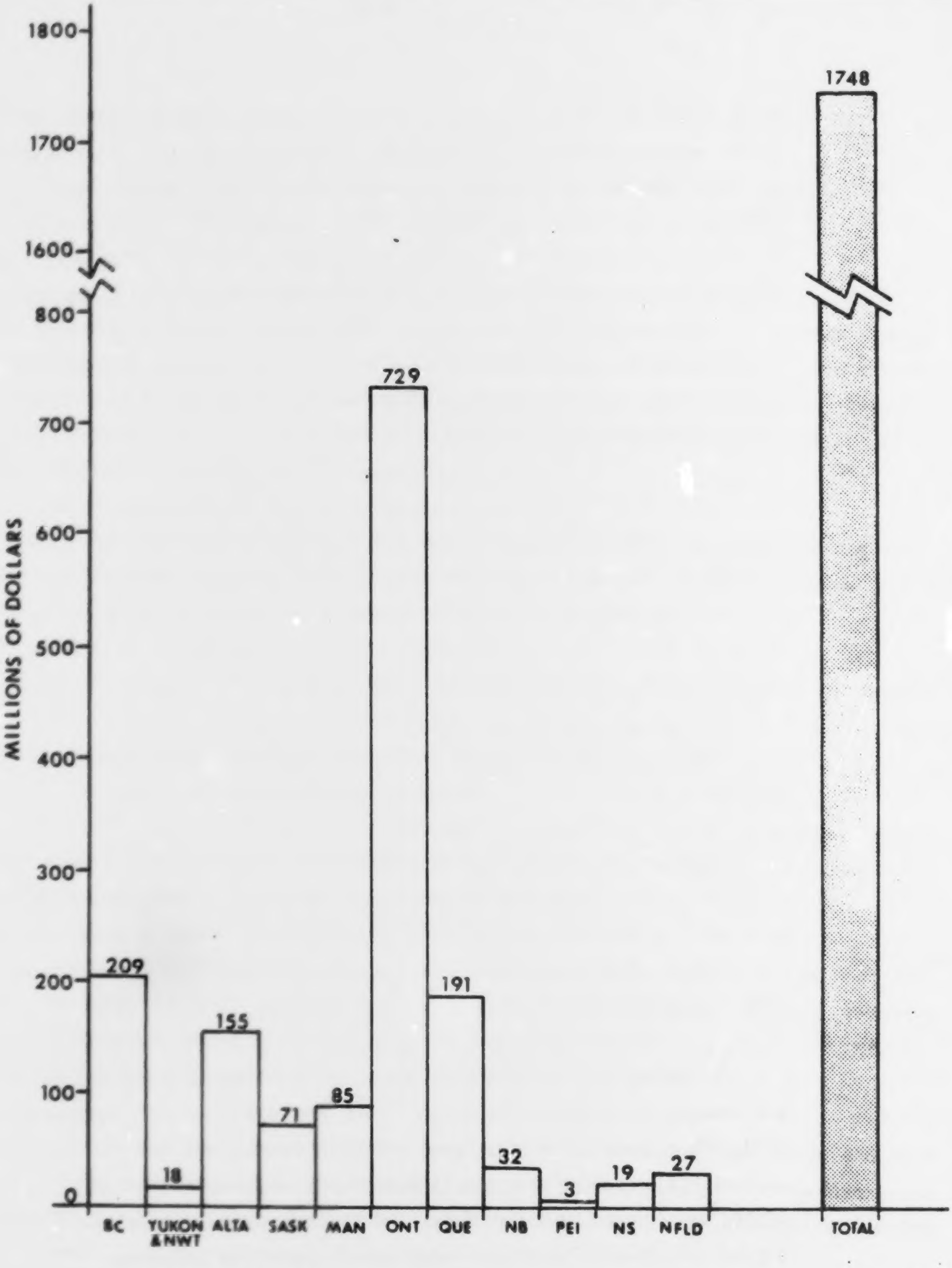

FIGURE II-4

Estimated sport fisheries values for 1980.
(Tuomi 1982)

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food, fish still constitute an appreciable proportion of the native diet. Various studies are now underway to address the problem of a lack of comprehensive data on domestic fish harvests in the Northwest Territories. Existing domestic fisheries information has been compiled mainly by proponents of Northwest Territories development projects, in particular, pipeline projects. The Mackenzie Valley Pipeline Inquiry reviewed the available domestic fishing data, which included results of surveys reported by Jessop et al. (1974) which focused on domestic fishing near Aklavik and Arctic Red River and determined that, in 1973, domestic catches in the Aklavik area amounted to approximately 134,000 kg, and approximately 58,700 kg for the Arctic Red River fishery.

Tester (1979) reported socio-economic and environmental information related to the proposed pipeline route for the Polar Gas Project in the eastern district of Keewatin. While it was noted that "it is extemely difficult to estimate the economic importance of domestic fishing to the Keewatin Inuit", available data on domestic catches in the Baker Lake area were reported to be between 65,000 and 157,400 kg, depending on the survey method as well as on annual variations.

McCart (1979) described Northwest Territories fisheries for several species. Regarding data on domestic fisheries, the following were noted:

Arctic char - for the Arctic char, domestic fisheries take place mainly for the anadromous form and mainly during the spawning season, when fishing is most efficient. It is likely that numbers of areas fished today is much less than in the past. Catch data are not available, but domestic char fishing remains an important aspect of native life.

Whitefish - three species of whitefish, humpback, broad and round whitefish, are caught in domestic fisheries. Data are available for humpback and broad whitefish in some areas, but round whitefish catches are not well recorded. Jessop et al. (1979) reported that the 1973 domestic catches in the Aklavik area included 32,965 kg of broad whitefish and 51,365 kg of humpback whitefish. For whitefish as a group, Northwest Territories catch data included the following:

Area	Period	Total Domestic Catch
Mackenzie Delta	1955-1975	201,402
Rankin Inlet	1960-1975	1,175,305
Cambridge Bay	1960-1975	651,307
Great Slave Lake	1945-1977	75,973,000

Lake Trout - domestic fishing occurs mainly in the Mackenzie Valley in drainages around Great Bear Lake and Great Slave Lake and near coastal communities on Coronation Gulf, Queen Maud Gulf and Hudson Bay. "Few reliable data are available concerning the number of lake trout taken"; however, approximately 3,500 kg of lake trout have been taken in the annual catch at Lac La Martre, and 1,800 kg at Tuktoyaktuk.

Pike - pike caught in domestic fisheries are generally used for dog food. Although there are no catch records, the highest catches are known to occur in the Mackenzie Valley and the Rankin Inlet and Baker Lake areas.

Inconnu - the inconnu, which is caught mainly in the Mackenzie Delta area, occurs mainly as an incidental species caught in gillnets set for other species, although it is also taken by angling. It is used for human and dog food.

Walleye - the walleye is present in Mackenzie Valley domestic catches; however, it is taken incidentally and there are no catch records. Because of its excellent flavour, it is most likely used for human food.

Grayling - grayling catches are also incidental to the catch of more important species. Although no domestic catch records are available, grayling domestic catches are known to be highest in the Mackenzie Valley. The grayling is used for human and dog food.

Arctic cicso, least cisco and lake cisco - Arctic cisco, least cisco and lake cisco are caught in domestic fisheries, mainly in the northern part of the Mackenzie Valley, in Great Bear Lake and Great Slave Lake. They are used mainly for dog food.

British Columbia

British Columbia has a population of 34,504 native peoples on reservations. There is no accurate method of measuring the monetary value of the salmon stocks to the native people in British Columbia. Catch data for the Fraser River domestic fisheries are summarized in Table II-4. In recent years, average annual catches for all species have totalled approximately 398,928 fish. In 1973, a study of the cultural relationship between native peoples and the salmon of the Fraser River - jointly sponsored by the Department of Fisheries and Environment and the Union of British Columbia Indian Chiefs was completed (Bennett 1973). The following excerpts summarize the cultural and subsistence role identified by Fraser River Bands.

> "The water itself is part of the traditional Indian way of life. Most reserves are located on or within one-half mile of the system's waterways. Changes in the riverine environment would disrupt the established link between the people and the river - a significant aspect of Indian existence.
>
> The fishery resource provides part of the food supply for a very high proportion of Indian families. If the fishery were adversely affected, a large number of Indians would be without sufficient food. It is doubtful whether alternative forms of sustenance would be acceptable. Most of those sampled said they would not substitute other foods in place of fish in their diet. Furthermore, because of the fact that fishing is a fundamental part of their lives, the loss of the fishery would detach the Indian people from the culture which they have developed throughout the centuries."

Although the study referred specifically to the Fraser River system, it is likely that the relationship of the native people to salmon, rivers and estuaries is similar in other important river systems of British Columbia.

2.2 Water-Associated Recreation

The report entitled Canada Water Year Book 1975 (Environment Canada 1975) contained a concise review of data available on the participation by Canadians in water-oriented recreation. Pertinent information has been extracted from this publication in the following paragraph.

Table II-4 Summary of annual catch data by species in the Fraser River domestic fisheries (Schubert 1983).

Period	Annual Average Catch						Total
	Chinook	Sockeye	Pink	Coho	Chum	Steelhead	
1978-1982	19,480	317,138	58,784	25,521	12,089	1,186	398,928
1971-1980	17,245	212,203	42,653	20,878	9,624	1,623	282,900
1961-1970	10,634	142,594	28,796	15,811	9,327	3,490	196,254
1951-1960	8,427	83,580	12,534	6,808	6,618	2,691	113,805

Outdoor recreation in Canada includes a variety of activities, including hiking, swimming, sightseeing, boating, picnicking, camping, fishing, and many others. Activities involving the use of water resources are listed in Table II-5. The water-oriented activities most frequently engaged in were swimming, picnicking, sightseeing from a private vehicle and walking or hiking. These were also the water-oriented activities that required the least preparation or specialized equipment. Lower frequency of participation was evident in activities that required special equipment and specific skills, such as sailing or water-skiing. The most frequently occurring water-oriented activity was swimming. In 1969, 44% of people 18 years and over went swimming at least once. The second most frequent activity was sport fishing. Information on the value of sports fishing was described previously in subsection 2.1.

2.3 Hunting

Waterfowl hunting is a popular activity for Canadians. Since 1966, the number of federal migratory bird hunting permits sold annually ranged between 380,000 and 525,000 (Environment Canada 1985). In 1980, 498,916 permits were sold; 385,396 hunters were reported to engage in hunting, and they bagged 4,148,518 migratory waterfowl (Table II-6). The average take per hunter therefore was approximately 11 birds. Almost half (45.6%) of the hunting permits were issued to hunters in Ontario and Alberta.

Data compiled by Environment Canada on the dollar value of waterfowl to users and the costs incurred in utilizing and preserving the resource are summarized in Table II-7. For 1980, the total expenditures of waterfowl hunting were approximately 274 millin dollars. Resident hunters as a group incurred the greatest expenditures (157.8 million dollars). The costs for gaining access to waterfowl was estimated at 85.2 million. Equipment costs (for goods such as recreational vehicles, special clothing, decoys, guns, etc.) were 69.5 million, and permits and licences (pro-rated for waterfowl) cost 3.1 million. Altogether, resident hunters spent 157.8 million dollars for 1980.

Table II-5 Percentage of Canadians participating in selected outdoor water-oriented recreational activities by region, 1967, 1969 and 1972 (% of Canadians 18 years and over participating at least once) (Source: Environment Canada 1975).

Activity	Atlantic			Quebec			Ontario			Prairies			Pacific			Canada		
	67	69	72	67	69	72	67	69	72	67	69	72	67	69	72	67	69	72
Water-Based																		
Swimming	36	36	-	31	40	-	47	53	-	29	37	-	49	46	-	39	44	-
Power boating	12	14	13	11	14	25	19	23	23	12	17	22	20	24	31	15	19	23
Canoeing	3	2	2	3	9	11	8	10	11	3	6	7	3	5	12	5	8	10
Sailing	-	5	3	-	2	4	-	4	6	-	2	2	-	2	7	-	3	5
Water skiing	3	2	-	5	5	-	9	9	-	7	9	-	9	7	-	7	7	-
Canal Tour-Boats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Fishing	33	-	31	21	-	29	29	-	30	22	-	33	31	-	39	27	-	31
Freshwater	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29
Salt water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Hunting	21	15	21	11	12	10	12	10	8	11	15	12	15	16	15	14	13	11
Waterfowl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Water-Enhanced																		
Tenting	15	11	13	11	13	18	13	10	19	11	13	19	21	14	24	14	12	19
Trailer Camping	8	4	9	5	5	8	6	4	10	8	8	14	10	7	11	7	6	10
Camping (pickup camper)	-	3	2	-	1	2	-	1	2	-	3	5	-	6	15	-	2	4
Sightseeing (private vehicle)	-	48	38	-	19	15	-	54	45	-	51	53	-	55	56	-	43	38
Picnic/cookouts away from home	42	50	50	33	48	46	44	56	56	48	58	61	45	58	55	42	54	54
Walking/hiking	-	28	26	-	41	43	-	39	38	-	28	36	-	45	46	-	37	39

Table II-6 Migratory waterfowl hunting in 1980 (Source: Environment Canada 1985, from Canadian Wildlife Service Progress Note No. 126).

Province/Territory	Number of Hunting Permits Sold	Waterfowl (Ducks and Geese) Active Hunters	Waterfowl (Ducks and Geese) Retrieved Kills	Waterfowl (Ducks and Geese) Recreation Days
Newfoundland	31,362	19,608	116,855	221,289
Prince Edward Island	5,802	4,789	50,756	57,880
Nova Scotia	14,257	10,853	133,174	105,302
New Brunswick	12,471	8,534	62,979	62,426
Quebec	76,133	59,159	623,275	527,142
Ontario	147,952	112,927	998,150	849,084
Manitoba	48,340	41,815	505,275	274,877
Saskatchewan	54,081	46,611	614,943	294,156
Alberta	79,318	61,958	821,998	417,458
British Columbia	27,943	17,617	205,025	148,947
Northwest Territories	732	1,157	12,538	7,286
Yukon	525	368	3,550	1,756
Canada	498,916	385,396	4,148,518	2,967,603

Table II-7 Estimated dollar values for waterfowl hunting and related expenditures in 1980 (Source: Environment Canada 1985).

	Expenditure By Purpose		Total
		millions of dollars	
Indian and Inuit Hunters	To Procure Food	5.1	5.1
Resident Sport Hunters	Access	85.2	
	Capital Items	69.5	
	Licences	3.1	157.8
Bird Watchers	Access and Capital Items	62.4	62.4
Ducks Unlimited	Restore and Preserve Habitat	18.5	18.5
Governments	Conservation and Management	12.3	
	Compensation to Farmers	2.1	
	Damage Prevention	1.0	15.4
Farmers	Waterfowl Damage	n.d.	
	Compensation for Damage	n.d.	7.9
Airlines	Direct Damage	0.9	
	Damage Prevention	0.7	1.6
			274.0

The second largest expenditure group was bird watchers which in 1980, included approximately 2 million adults (Environment Canada 1985), who spent 62.4 million dollars on services and supplies for bird watching, the main expenses being mainly for access to waterfowl areas and for photography.

The Canadian Wildlife Service (CWS), in cooperation with the provinces and the territories, has implemented programs to ensure that each migratory bird species is preserved and that a surplus is produced to support waterfowl hunting in Canada and in the United States. The programs focus on preserving wetland habitat, including the pothole breeding habitat in the grain production region of the prairies, as well as large marshlands. The distribution of breeding habitat is shown in Figure II-5.

To protect pothole habitat, landowners have agreed, in return for financial compensation, not to drain or fill wetlands or burn the vegetation around them. Marshland protection also has involved programs to maximize waterfowl carrying capacity by controlling water levels, modifying the shoreline, and planting more suitable food and cover species. Such efforts to maintain habitat and improve numbers has been determined to be necessary because of the value of the resource.

2.4 Trapping

The fur industry for Canada relies on two main sources for its furs: furs from wild animals caught in traps; and furs from farm animals, raised in controlled conditions (Environment Canada 1975). This section will deal only with the trapping of wild animals because of their dependence on water resources.

Wild animals that are trapped for furs are muskrat, beaver, squirrel, hair seal, mink, fox, marten, otter, ermine, racoon, rabbit, coyote, linx and fisher (Environment Canada 1975). The quantity and dollar value of pelts from aquatic and semi-aquatic mammals taken in the 1981/82 season are indicated as follows (Environment Canada 1985):

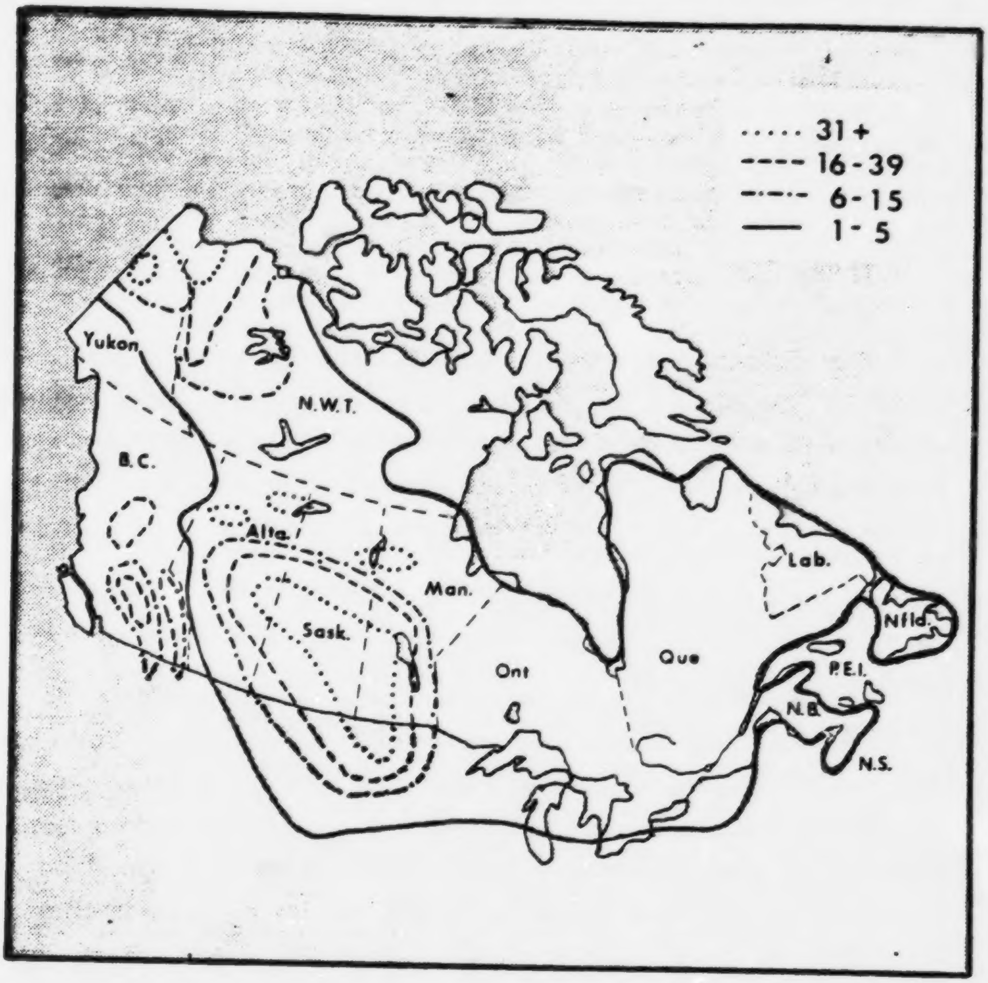

FIGURE II-5
Migratory waterfowl breeding pairs per square mile. (Source: Environment Canada 1975)

Mammal	Number of Pelts	Value (dollars)
Beaver	382,893	$8,531,693.00
Muskrat	1,526,086	6,506,473.00
Otter	19,643	1,049,958.00
Mink	105,117	3,029,079.00
TOTAL	2,033,739	19,117,203.00

This production represents approximately 33% of the total 1981/82 fur production valued over 58 million dollars. In addition, other water-associated mammals including racoon, marten, fisher, weasel and bear also were trapped. Some examples of the 1981/82 value of these animals include racoon at 5.8 million and marten, also at 5.8 million (Environment Canada 1985).

2.5 Aesthetic Enjoyment

For Canadians in general, who view and/or have knowledge of the appearance of the environment, its aesthetic value cannot be quantified. Some site-specific information on aesthetic values is available as a result of broader assessments of environmental resources and the feasibility of potential recreation programs; often these studies have determined aesthetic values in terms of opportunity costs, i.e. the costs an individual would be willing to incur for aesthetically pleasing experiences, but because aesthetic values are so individually oriented, the aesthetic effect of an experience will vary from person to person.

In general, though, Canadians put a higher value on natural landscapes than landscapes with human activities and development; and within an environment that contains substantial development, such as cities or large development projects, the presence of a waterbody in the surroundings greatly improves the aesthetics. This is the basis for our attraction to and appreciation of public fountains in urban parks and in city plazas. Water is a highly important component of the aesthetic value of the landscape and our appreciation of it can be seen to reflect very basic human needs. Some theoretical aspects of aesthetics were reviewed by Wall (1978) who noted the following:

> "Water has had an enduring fascination for man, a fascination which appears to transcend time and culture. It is legitimate to enquire what the basis of this fascination might be on the premise that an answer to such a question might be highly relevant to the planning and management of water-based recreational opportunities. Perhaps a partial answer can be found in Appleton's "habitat theory" of landscape (Appleton, 1975). Appleton sees man's most basic concern as biological survival i.e. hazard avoidance. In order to protect himself from hazards man likes to be able to see without being seen. This, in a nutshell, is "prospect-refuge theory", prospect meaning view and refuge meaning an environmental condition, situation, object or arrangement conducive to hiding or sheltering. Habitat theory postulates that aesthetic pleasure in landscape derives from the observer experiencing an environment favourable to the satisfaction of the biological needs. Prospect-refuge theory postulates that, because the ability to see without being seen is an intermediate step in the satisfaction of those needs, the capacity of an environment to ensure the achievement of this becomes a more immediate source of aesthetic satisfaction (Appleton, 1975, p. 73). Furthermore, this frequently occurs at a symbolic level and no hazard need be present".

While the aesthetic value of a waterbody cannot be quantified, each person who perceives its aesthetic quality subjectively judges his perception by comparing various features of the waterbody with those of other waterbodies or with features that the individual understands to be contributing factors to aesthetic quality. Typically, the aesthetic pleasure of a waterbody depends on the clarity of the water, its setting in the landscape, the interplay between the water's surface and the shoreline, and the type and extent of human use of the waterbody. Its aesthetic quality will diminish if human actions cause changes in the water's appearance or in the way it feels, tastes or smells. EPS (1974) recommended that to maintain aesthetic quality, discharges into the waterbody of "objectionable" materials, and the effects of the materials must be minimized. The objectionable materials were noted as follows:

> "Materials that will settle to form objectionable deposits:
>
> - floating debris;
> - scum and other matter;
> - substances producing objectionable color, odor, taste or turbidity;
> - substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life."

3.0 WATER USES FOR TRANSPORTATION

3.1 Freight Transport

Although present-day use of highway transport vehicles, aircraft, railways and pipelines has reduced the use of waterways for transporting freight "water still provides the most economical means of transporting the important bulky raw materials of Canada's export trade - wheat, pulp and paper, lumber, mineral..." (Environment Canada 1976). The most significant transport waterway is the St. Lawrence Seaway which has cost several billion dollars for construction and operation and another several billion dollars for wharves and other shipping facilities. Summary data on cargo traffic through the St. Lawrence Seaway are presented in Table II-8. In 1982, more than 42 million tonnes of cargo were shipped through the Montreal-Lake Ontario section, and approximately 49 million tonnes through the Welland Canal.

Other inland waterways initially developed for shipping, but which are now used mainly for recreation, include the Trent Canal, the Rideau Canal, St. Anne. de Bellevue Canal, Carillon Canal, Chambly Canal and the St. Ours Canal.

Other than the Great Lakes-St. Lawrence system, the only major inland navigation route is the Mackenzie River Basin system which, in 1972, carried over 400,000 tons of general and bulk cargo. This tonnage is relatively small, but because the Mackenzie basin does not have an extensive road or rail system, the shipping volume is highly important (Environment Canada 1976). Transporting cargo on the Mackenzie system involves dealing with problems created by ice, climate, rapids, shifting channels and low water levels after the freshet. The lowest freight traffic occurs early in the season when high water levels provide good navigation. The traffic tends to increase through the summer and reach a peak late in the season when flows are low and unfavourable fall weather conditions occur.

In other areas of Canada, important transportation activities occur in estuaries and river mouths. In British Columbia, numerous harbours operate in

Table II-8 Traffic in the St. Lawrence Seaway 1981, 1982 (Source: Environment Canada 1985).

General Statistics	1981	1982
Montreal-Lake Ontario		
Total cargo (tonnes)	50,569,314	42,815,314
Total vessel transits	4,628	4,376
Traffic split (%)		
Upbound	37	26
Downbound	63	74
Welland Canal		
Total cargo (tonnes)	58,850,875	49,024,104
Total vessel transits	5,960	5,184
Traffic split (%)		
Upbound	28	18
Downbound	72	82

Cargo Traffic by Principal Commodity (millions of tonnes)

Commodity	Montreal-Lake Ontario		Welland Canal	
	1981	1982	1981	1982
Grain	24.46	24.27	25.57	25.19
Canada	(13.51)	(15.95)	(14.10)	(16.47)
United States	(10.95)	(08.32)	(11.47)	(08.72)
Iron Ore	12.93	7.43	13.74	7.02
Coal	1.68	1.15	6.58	7.14
Other Bulk	8.09	6.79	10.23	7.66
General Cargo	3.41	3.18	2.73	2.01
	50.57	42.82	58.85	49.02

estuary channels, including the north and south arms of the Fraser River, the Nanaimo River and Squamish River estuaries. In 1981, coastal cargo traffic in British Columbia amounted to 25.95 million tonnes loaded (Environment Canada 1985). The mouth of the Churchill River in Manitoba is an important harbour for grain ships and other vessels. International cargo loaded at Churchill in 1981 amounted to 451,475 tonnes. Numerous estuaries in eastern Canada also contain harbour facilities. Much of the traffic in estuaries and river mouths involves local movements of forest industry products, fishing vessels, marine service vessels including dredges, pile drivers and marine research ships, and commercial boats such as tour boats, water taxis and fishing and diving guide boats.

3.2 Forest Industry Log and Pulpwood Transport

The most recent available information on log and pulpwood transport includes the following information extracted from Canada Water Year Book 1976 (Fisheries and Environment Canada 1976). As of 1976, approximately 40% of all pulp and saw logs were transported by water. Historically, nearly all major log transport was by river driving and the forest industry's right to use rivers for log driving was secured by laws, enacted by parliament as early as 1867, that benefited log driving by enabling the use of booms, slides and other in-river facilities. In the last 40 years, efficient land transport services have provided less expensive means to deliver logs. However, in areas where road or rail systems are not in place or where delivery distances exceed 160 km, water transport remains the more economical system.

Log driving has negative environmental effects and can affect recreational activities by limiting or precluding use of or access to fishing and other areas used for other water-related recreation. These effects are discussed further in section III, subsection 3.1.2.

4.0 WATER USE AND VALUE FOR POLLUTION MANAGEMENT

Managing water resources requires technical, social and economic consideration of the use of the water for pollution. Existing pollution control legislation, regulations and guidelines are directed at controlling pollution discharges by prescribing maximum allowable quantities of pollutant in the effluent as well as in the effluent receiving waters. Effluent standards and guidelines are usually federal, and receiving water objectives provincial or territorial. Both approaches are essential to protect specific water resource uses. Federal effluent quality standards are listed in Appendix II. Table II-9 provides examples of Canadian water quality objectives for ten pollutant metals in relation to seven water resource uses. For each metal, the prescribed objective varies among the different water uses. Pollution management difficulties can arise under conditions of multiple water resource use and conflict over the priority of use. In addition, when applying water quality objectives to specific locations, consideration must be given to local characteristics of weather, soils, geology, plant communities and animal populations. It is important that water quality objectives protect the most critical species, therefore it is essential to develop a full understanding of the biology and local ecology of the most critical species. In general, the welfare of critical species can be protected if the following provisions are met (quoting Reader 1979):

"1. Quality and overall values of waters in Canada are protected and enhanced to meet the requirements of all foreseeable uses of water and that:

   a) the quality of any body of water and life system functioning within that waterbody should not be allowed to deteriorate below minimum acceptable levels consistent with current knowledge and practicable technology, or if below, the quality of the waterbody should be brought up to a minimum acceptable quality;

   b) certain 'high quality' bodies of water whose existing quality is substantially above existing requirements should be maintained at their existing high levels of quality.

2. Where natural conditions are suitable, all bodies of water should be of sufficiently high quality to permit safe, direct body contact.

3. All water should meet minimum national or international standards and objectives (statutory, recommended or agreed) designed for the protection and enhancement of public health and well being.

Table II-9 Canadian recommended surface fresh water quality objectives (mg/L as total metal) (from Reader 1979).

Constituent	Raw Public Water Supply	Aquatic Life and Wildlife		Agricultural Water Supply		Recreation	Food Processing
		Aquatic Life	Wildlife	Livestock	Irrigation		
Volume 1 - Inorganic Chemical Substances							
Arsenic	0.05	0.05	*	0.5	0.1 (sensitive crop, sandy loam)	0.05	0.05
					1.0 (sensitive crop, clay)		
					1.0 (tolerant crop, sandy loam)		
					2.0 (tolerant crop, clay)		
Cadmium	0.01	0.0002	*	0.02	0.01	0.01	0.01
Chromium	0.1	0.04	0.04	1.0	0.1	0.1	0.1
Copper	0.5	0.002	0.002	1.0 (sheep and cattle present)	0.2 (continuous use, sensitive plants)	0.5	0.5
				5.0 (all other cases)	1.0 (less sensitive plants)		
					5.0 (short term use)		
Lead	0.25 (conventional treatment)	0.005 (hardness $\leq$ 95 mg/L as $CaCO_3$)	0.005 (hardness $\leq$ 95 mg/L as $CaCO_3$)	0.5 (horses present)	5.0 (continuous use)	0.05	0.25 (conventional treatment)
	0.05 (disinfection only)	0.01 (hardness > 95 mg/L as $CaCO_3$); waters with sensitive species of fish	0.03 (hardness > 95 mg/L as $CaCO_3$)	1.0 (horses absent)	10.0 (intermittent use)		0.05 (disinfection only)
		0.03 (hardness > 95 mg/L as $CaCO_3$; sensitive species of fish absent)					

Table II-9 Cont'd.

Constituent	Raw Public Water Supply	Aquatic Life and Wildlife		Agricultural Water Supply		Recreation	Food Processing
		Aquatic Life	Wildlife	Livestock	Irrigation		
Mercury	0.001	0.0001 (to protect consumers of fish)	0.003 (see mercury content of fish for fish eaters)	0.003	no recommendation	0.001	0.001
		0.0002 (where fish not eaten)					
Nickel	0.25 (conventional treatment)	0.025 (soft water)	0.025 (soft water)	5.0	0.2 (continuous use)	0.25	0.25
		0.25 (hardness > 150 mg/L as $CaCO_3$)	0.25 (hardness > 150 mg/L as $CaCO_3$)		2.0 (intermittent use)		
Selenium	0.05 (simple treatment)	0.01	0.01	0.02 minimum	0.02 (continuous use)	0.05	0.05 (simple treatment)
	0.25 (conventional treatment)			0.05 maximum	0.05 (intermittent use)		0.25 (conventional treatment)
Silver	0.05 (no treatment or simple treatment)	0.0001	*	*	*	0.05	0.05 (simple treatment)
	0.2 (conventional treatment)						0.2 (conventional treatment)
Zinc	5.0 (simple treatment)	0.05 (hardness 0-120 mg/L as $CaCO_3$)	0.05 (hardness 0-120 mg/L as $CaCO_3$)	50.0	1.0 (soils pH < 6.5)	5.0	5.0 (simple treatment)
	10.0 (conventional treatment)	0.10 (hardness 120-180 mg/L as $CaCO_3$)	0.10 (hardness 120-180 mg/L as $CaCO_3$)		5.0 (soils pH > 6.5)		10.0 (conventional treatment)
		0.20 (hardness 180-300 mg/L as $CaCO_3$)	0.20 (hardness 180-300 mg/L as $CaCO_3$)				
		0.30 (hardness > 300 mg/L as $CaCO_3$)	0.30 (hardness > 300 mg/L as $CaCO_3$)				

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* Insufficient information to set a defensible limit.

4. The quality of water should be maintained so as not to impede an optimum, sustainable economic yield of Canada's fish resources compatible with other desired users of water.

5. All water should be maintained free of any substances which pose a threat to the aquatic or human environment or within concentration limits for all constituents designated under appropriate legislature respecting environmental contaminants. Such a freedom or limitation should be corroborated by biological assessment.

6. All water should be free of amounts of substances attributable to municipal, industrial and other discharges that will settle to form putrescent or otherwise objectionable deposits that produce colour, odour and other conditions to such a degree as to create a nuisance or in concentrations that are toxic or harmful to human, terrestrial or aquatic life.

7. All waters should be free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges (including those from ships and other waterborne vehicles) in amounts sufficient to cause unsightly or deleterious effects on water quality.

8. All waters should be free from nutrient substances derived from municipal, industrial, agricultural or other sources in concentrations or quantities that create nuisance growths of aquatic macrophytes and algae."

III PROBLEMS WITH ALLOCATION OF WATER FOR INSTREAM RESOURCE NEEDS AND VALUES

This section reviews the conflicts that can occur over the various uses of instream water resources. There have been numerous Canadian water use conflicts and the critical issues of each conflict have been unique and complex. Major conflicts have occurred in every province and territory as a result of water resource allocation projects or proposals. Some of the more notable examples include the McGregor River diversion, and the Kemano Completion Project in British Columbia, the Churchill River diversion in northern Manitoba, the James Bay project in Quebec, and the Churchill Falls hydro power development in Labrador. To review the water use conflicts and the specific issues involved in these and other important developments would be the task of a separate, much larger study. The following sections, while noting some examples of certain types of conflicts, focus on the issues that are generally involved in three major areas of instream resource use conflicts: conflicts among instream uses, conflicts between instream and offstream water uses, and conflicts between instream water use and land use.

1.0 BACKGROUND

Personnel in fish and wildlife agencies having mandates to protect these resources, often are so conservative in their estimate of instream needs that there is little or no water left for other potential water resource use. Hydro power, irrigation scheme and potable water supply developers often state that, unless they receive water allocations requested in their licencing or water right applications, their schemes are "uneconomic".

Of course, the reality is that the majority of watercourses have water quantities above the needs of instream users, particularly during flooding periods. Most water development schemes also have a lot of economic and engineering flexibility to accommodate instream resource needs, if they are clearly determined.

In the past, most water resource developments have occurred with little regard to instream resources (some developments shut off water flows entirely on watercourses) or, if they were considered, small mitigation measures were tacked onto the scheme after it had already been optimized for the offstream development.

With the increase in environmental awareness of instream resource values and better knowledge of instream resource needs, most water development schemes now involve a more equitable allocation of water to the different resource users. However, a number of prejudices and attitudes remain among instream and offstream water resource users.

The following are examples of these biases:

1. Among Instream Resource Managers and Users

a) Any change in the status quo of a natural system will result in negative effects on instream resources (i.e. "Mother Nature knows best").

Any proposed development of a water resource is viewed with grave concern by most instream resource managers, although when developing their own resource interests such as fish, the first step is to change and control the environment in which fish are raised in hatcheries, dammed watercourses, off-channel spawning and rearing channels, by temperature manipulation, etc.

Natural systems could be the most suitable for instream biological resources in the long run if man were not exploiting the resources and if man were prepared to wait long periods for those populations to recover from natural impacts, catastrophes such as severe floods, landslides, droughts, etc. However, society has determined that it is in the best public interest to maintain a constant and, if possible, increasing supply of biological resources in watercourses. The way to best achieve, preserve and enhance these resources is to create a fairly steady-state water system, with only limited controlled flood events and, if possible, no droughts. Shoreline substrate stability can also be improved and natural slides, if they occur, removed. These features can often be designed into offstream water developments.

b) More water equals more fish.

In a recent study of water management on a west coast river, the following statement is made in a background report:

> "...that flows through Port Coquitlam have been reduced to about 1/5 of what they were before the dam was constructed. It would seem reasonable to assume that productive capacity of the river for salmonids have been similarly reduced" (Arber 1978).

The assumption is made that fish numbers are directly related to water flow. There is a linear year relationship between fish resources and water quantity from the zero flow in a stream up to some point usually at which the wetted area in the streambed is maximized. However, after that point is reached, and flows continue to increase, there is an inverse relationship between the numbers of fish which can be produced in a stream, and flow. The above statement, therefore, is not correct.

Most fish resource managers and other water investigators realize that more water does not necessarily mean more fish. However, this professional realization is often overcome by personal prejudice when an actual decision must be made on how much water to allocate to biological instream resources and to other users in the stream systems. This prejudice is well based on past experience by the instream resource managers where other water users got more than their share in a water allocation scheme, or where mistakes were made in determining what amounts of water were actually necessary for supporting fish populations. This leads to a lack of trust on the part of the instream resource managers of the whole water resource allocation mechanism and extreme conservatism on their part in estimating the actual needs of the instream resources in the system. Water flow allocation mechanisms in Canada must address these attitudes held by instream resource managers in order that rational water allocation schemes can proceed.

c) All dams are bad for fish resources.

Most major fish resource enhancement schemes involve placing a dam on the river being developed, or placing the enhancement structures off to one side of a river channel, so that flows can be controlled. However, fisheries resource management people regard dams generally as being harmful to fish. Many dams certainly have harmful effects on fish and have devastated formerly healthy populations. However, dams can also be designed and managed in such a way that downstream and upstream fish resources can be significantly enhanced and developed. Innovation in ways to accomplish fish resource development, along with dam development, has been held back in Canada because of the prejudice of the fishery manager and fish resource users against dams. Fish resource interests often mount opposition stances to any dam scheme and sometimes win. However, if overriding political or society interests dictate that the dam projects go ahead despite the position of fish resource interests, the latter are often forced to settle for a relatively minor mitigation compensation scheme which is tacked on to the dam project as long as it does not interfere with the maximum offstream benefits of the dam. Opportunities exist for far greater benefits to be created for fish if the fish managers present more positive options for managing flows to benefit downstream fish populations and managing reservoirs to benefit upstream populations. This also requires considerable flexibility on the part of the dam designers and facility management. Much of the technology and methodology for improving water basin dam and fish and wildlife resource compatibility is presently being developed by studies and facility construction under the direction of the Northwest Power Planning Council (1982) on the U.S. Columbia River system.

2. Among Offstream Resource Use Proponents

a) Any change to a water development scheme from that which is proposed is "uneconomic".

In the past, many water development schemes have been developed, based on economic and engineering feasibility only. Other factors, such as instream resources which have sometimes been considered in the past, have been added on after the engineering and economic factors have been entrenched and established for the project. This has resulted in instream resources not being really allocated the water or the consideration they deserve. Water development managers, who are usually engineers, resent any interference with the technical and maximum economic parameters of their scheme.

In more recent years, however, environmental instream resources have been considered from the very beginning, at the conceptual stage of a project. Studies of these resources have produced much more in the way of data to evaluate instream resources which might be affected by a project. However, even in recent years, the total optimization of a water management scheme has often not been done. Such an optimization analysis would consider instream resource values as significant constraints or opportunities to develop the project in its most beneficial form for all of society's values. This is not by any means an impossible task, either technically or politically, as far as creating an atmosphere for dialogue among all participants. However, it does require considerable tolerance, flexibility and imagination on the part of water development proponents, and also requires unbiased, objective input from instream resource managers. It also requires instream resource managers to contribute to the development of a scheme for which the flow parameters and design have not yet been established. This often makes the instream managers uncomfortable in that they are more accustomed to reacting to specific development proposals rather than defining their own instream resource needs and management policies at the beginning of a water allocation process.

b) Offstream benefits are so overwhelmingly more valuable than instream resources that the latter do not warrant much consideration.

Careful economic analyses of all the real benefits derived from a water development scheme are useful in analyzing which benefits should receive priority in terms of water allocation, enhancement, and protection. However, any economic analysis of a water development scheme has to also take into consideration the so-called intangible benefits, not usually measured, that might accrue from the scheme.

In any match of offstream economic benefits compared to measurable instream economic benefits, the instream benefits are usually lower in a time frame which is foreseeable or generally used for the project stretching over perhaps 20 or 25 years. However, taking a longer time frame and including so-called intangible benefits changes the picture considerably. There have been attempts made in the past to quantify these intangible benefits with varying success. For the purposes of the discussion here, it is enough to point out that water resource managers should be very much aware of these benefits and treat them as importantly as straight economic benefits. During the development and discussion of a water development scheme, appropriate weights for the intangible benefits should evolve out of the review and discussion process. Public input into ensuring the appropriate weight is put on these benefits should be sought during the development of the scheme so that these values are protected and, if possible, maximized. More discussion of how instream values are not easily measured by normal economic means is in section IV, subsection 4.0.

2.0 CONFLICTS AMONG INSTREAM USES

2.1 Water Quality Changes

2.1.1 Fish vs. Pollution

Lakes and rivers traditionally have been regarded as suitable repositories for wastes and pollutants because of the capacity of the waterbody to assimilate the wastes by dilution, by carrying them away from the discharge points, and by biochemical processes that break down the waste material and incorporate the components into the environment.

Historic and new sources of industrial wastes that degrade water quality are numerous across Canada. Water quality reduction by industrial wastes results in fewer fish utilizing the water systems receiving the wastes. Pollution is more prevalent in heavily populated areas and fish productivity in freshwater habitat in these areas is also generally lowest. Pulp and paper waste, tailings and pit drainage from mines, refinery effluent and pollution from other general industry contribute to this problem. Although significant improvement of waste treatment before discharge to a natural system has taken place in recent years, the sheer increase in the number of these pollution sources frequently causes a water system's assimilative capacity to be overwhelmed. Examples of major systems where this capacity is being approached, or has been exceeded, are the Lower Fraser River in British Columbia, the St. Lawrence River in Quebec, and the St. John River in New Brunswick.

Some pollution of watercourses does not appear to affect the viability of fish resident in them, but makes their flesh unfit for human consumption because of contamination with dangerous levels of mercury, chlorinated hydrocarbons, polychlorinated biphenols, or sewage. Thus, entire commercial, sport and native fisheries are closed. Examples of such areas occur in both the Pacific and Atlantic coasts and in inland areas, the most notorious being the English-Wabigoon system of northern Ontario.

2.1.2 Fish vs. Timber Transport

Most of the recent attention to the effects of logging industry activities on the aquatic environment have focused on the impacts of various forest clear-cutting practices, overland transport of timber and coastal storage booming and other handling of logs. Relevant to log driving effects is recent information on stream channel and aquatic ecosystem changes caused by the following (Dorcey et al. 1980).

Physical Effects - log rafting and driving can cause physical effects that include bank and channel scour that removes important habitat, log jams that create increased velocity and other hydraulic processes that substantially reduce the amount of habitat present in the vicinity of the log jam, burial of important substrate by sedimentation caused by scouring, and by log jams, physical barriers to fish movement caused by log jams, and in areas of water level fluctuations, such as reservoirs and intertidal river channels and estuaries, substrate compaction and crushing can occur which causes reduction in benthos abundance and density.

Log Bark Effects - friction between logs, rafts and booms releases bark and wood particles that can bury sessile organisms and, if sufficient amounts of particles settle on the bottom, they can prevent motile animals from moving from the area. Fine wood particles that sink to the substrate can clog the spaces in gravel beds that can contain fish egg embryos and recently hatched fry. The decomposition of bark and fine wood particles also affects aquatic habitat by increasing the biological oxygen demand and depleting oxygen levels in the water.

Leachate Effects - leachates include organic acids, tannins and lignins that are released by bark and wood in water. Leachates can be toxic to fish, and at lower concentrations, can have sublethal effects. The effects of leachates can also include increased biological oxygen demand and decreased oxygen levels in sheltered, low-velocity areas. Excessive growths of tolerant algal species can occur which, during their die-off periods, can also increase biological demand and decrease dissolved oxygen levels.

Light Reduction Effects - the bank and channel scour effects of log rafts and log jams can increase turbidity and therefore reduce light transmission into the water column. The log rafts and booms themselves also create substantial additional shade in stream channels. These light reduction effects reduce the amount of photosynthesis by phytoplankton and algae.

Channel Improvement Effects - aquatic habitat can be affected by activities such as dredging operations and the construction and use of training walls, jetties and piers for the transport of logs by water. The effects of these activities are summarized in subsection 2.2.1.

2.1.3 Water-Associated Sports vs. Pollution Management

The value of the water resource for recreational activities is directly related to the quality of the water. Nearly all water-associated sports involve direct contact, or at least the potential for direct contact, with the water. Swimming and diving, which involve the greatest amount of contact, are the most affected by reduced water quality, whereas activities that require little contact with the water, such as motor boating and nearshore camping, hiking or sight-seeing, are less influenced by water quality. For all activities, however, water quality affects the enjoyment of the activity by affecting the aesthetic value of the waterbody.

Pollution affects water-based recreation in various ways. Sewage pollution can cause increased levels of disease-causing bacteria. Urban and suburban swimming waters usually are sampled regularly to monitor bacterial growth, and if bacterial growth exceeds established maximum levels, health protection officials will find it necessary to close the swimming areas to public use. Agricultural runoff can contain animal waste that also can contribute to bacterial health hazards and can also contain chemical wastes, such as pesticides and herbicides, that can be directly dangerous to swimmers, divers and other recreational users of the water resource, particularly if concentrations are high, or if the runoff water or receiving water is not adjusted. Fertilizers also are health hazards and they can cause excessive algal and plant growth which can reduce the aesthetic value of the waterbody. Industrial wastes contain pollutants that can affect water-based recreation in several ways, including causing direct health hazards, causing ecological changes, such as plant and invertebrate die-off, which can affect shoreline features and reduce the value of the shoreline for recreation.

Fresh water fisheries, which in several areas of Canada have high economic values (section 2.1), are directly and indirectly affected by pollution through the effects of pollution on fish and fish habitat. These effects were noted previously in subsection 2.1.1.

2.2 Habitat Quantity and Quality Changes

2.2.1 Fish and Wildlife vs. Water Transport, Dredging, Terminal and Marina Development

The various uses of instream water resources can include activities that conflict with the needs of other uses. Habitat for biological resources can be changed by harbour development dredging operations and maintenance. Dredging removes important topographic features of the stream channel, such as lateral and transverse bars, that can contribute to the hydraulic features, and primary and second productivity required by fish and aquatic wildlife resources. Dredge spoil, in many cases, is deposited in the bird and wildlife habitat of nearby marsh and terrestrial environments, causing eradication of habitats as well as creating a source of sediments to be continually eroded back into the stream habitat. Dredging typically causes re-suspension of sediments which then move to downstream areas where sedimentation of important fish habitat can occur.

Bank stabilization and dyking operations replace complex natural microhabitat along shorelines with less usable channel bank features. Training walls, constructed in a dredged channel to utilize stream velocity for maintaining the depth of the dredged channel, can affect fish resources by directing young, downward moving fish away from important rearing areas, and can delay upward migrating fish moving towards spawning areas. Training walls also control the erosion and deposition of sediments which can also affect the suitability of instream fish habitat.

Shipping terminals, which typically are piers and wharves constructed by infilling the foreshore to the appropriate depth, and marinas, which involve the installation of floating piers, as well as the construction of wharves and fixed piers, cause impacts on fish resources through eradication of shallow nearshore habitat and by influencing the strength and direction of river currents. These hydraulic features control the route of sediment deposition, movements of young fish to littoral feeding areas and the movement of nutrients, invertebrate food organisms and the transport of wastes.

2.2.2 Fish vs. Water-Associated Bird Management and Enhancement

Conflicts exist between the use of shallow, well-vegetated shoreline areas, particularly marshes and sloughs, for the production of waterbirds such as ducks and geese, and for the production of fish species such as trout, salmon and walleye. Programs that involve the construction of weirs to control marsh water levels and modify channel and pond morphology to produce nesting grounds for birds, can preclude the natural use of the area as feeding habitat for the fry, juvenile and adult stages of the sport fish. Flow control structures can block fish spawning migrations and emigrations to traditional overwintering areas.

2.2.3 Wildlife vs. Recreational Boating

The use of water resources for recreational boating was noted previously in section II, subsection 2.2. It is a valuable leisure-time activity for which water allocations can be made to provide suitable instream conditions. As noted previously, natural shoreline areas are usually highly productive bird and wildlife habitat. Regulating flows for boating can result in abnormally high water levels that can displace birds and mammals, and inundate, erode and wash out productive bird and mammal habitat. The boating activity itself can also cause erosion (by wave action) pollution problems, and direct disruption of bird activities through increased human presence in the nesting, breeding and feeding areas.

3.0 CONFLICTS BETWEEN INSTREAM WATER RESOURCE USE AND OFFSTREAM WATER USES

3.1 Dams and Reservoirs

3.1.1 Fish vs. Dams and Reservoirs

Dams and reservoirs typically create negative effects on fish because of barriers created by the dam, transformation of stream habitat into lake habitat, and the direct and indirect changes that occur in the river below the dam. Negative effects can also occur during dam construction. Many dams and reservoirs constructed for offstream water uses have not resulted in net fisheries benefits. However, dams and reservoirs can create positive benefits for fish resources and the fisheries dependent upon them if they are designed and operated to benefit fisheries as well as to provide the primary benefits of the reservoir. In order that the fisheries benefits be achieved, reservoir proponents could have to forego certain economic benefits that would not be achieved if the project were to be operated within the environmental constraints that would benefit fish resources. Fisheries agencies and other parties with interests in the fish resources would need to be prepared to be cooperative in attempting to make theoretical fish benefits become real benefits through the development of workable administrative procedures in managing the reservoir operation.

The positive and negative effects of dams on fish are summarized in the following sections.

1. Positive Effects

a) Control or attenuation of spring and freshet flooding.

Providing operations are designed to allow for any necessary flushing flows to clean stream gravel, removal or reduction of flood peaks can benefit fish by:

- reducing the flushing of fish downstream to less suitable habitat

- reducing damage to spawning, incubation of rearing habitat caused by river morphology changes that result from floods
- reducing the stranding of eggs and juveniles when flood flows subside.

b) Augmentation of flows during low flow periods.

A common limitation of fish production in a system is the lowest wetted area of physical habitat during low flow periods. With the operation of a reservoir to augment natural flows during low flow periods, fish resources can be benefited significantly by increasing the wetted area which is often an approximation of rearing habitat. More spawning and overwintering habitat can also be created in this way.

c) Creation of reservoir fish resources and fisheries.

Reservoirs could be used to produce fish populations equal to or greater than the population that existed in the rivers or lakes that the reservoir replaced. Specific biophysical requirements would need to be met, such as shoreline stability, good water quality and gradual volume fluctuations, and some fish enhancement of these areas, such as hatcheries, juvenile planting or spawning area facilities, may be necessary to establish such populations.

d) Positive alteration of water temperature, freeze-up/break-up times and locations of anchor ice formations.

If flow regimes were established to positively alter the above factors to improve fish habitat and create more overwintering habitat, reservoir development could create benefits to fish.

2. Negative Impacts During Project Construction

a) Altered biophysical conditions.

Physical barriers, increased velocities, gravel removal from spawning and food production areas, reduced water quality, altered nutrient load, increased levels of pathological bacteria, stimulation of parasites, and undesirable vegetation growth can cause negative impacts on fish resources of a system.

b) Increased pollutant levels.

Increases in solid wastes, lubricating oil and antifreeze, fuels, chemicals, sewage, forestry-operations slash, pesticides and herbicides can result from dam construction activities.

3. Negative Impacts During Project Operation

a) Impacts on downstream migration.

Increased juvenile travel time downstream, increased predation and effects on ability to make transition from freshwater to saltwater, higher water temperatures, different water chemistry, and increased susceptibility to disease caused by dams can also affect fish.

b) Barriers to downstream migration and injury to downward migrants.

Dams can impede or block downward movements of fish from areas above the dam, and can cause injury to fish by pressure changes and by physical blows from passing through turbines, penstocks, spillways and flood gates. These injury effects can be directly lethal to fish or can result in increased predation below dams because of the fish's increased disorientation or injury.

c) Impacts on upstream migrants.

Fish can be affected by dams creating migration barriers to upstream migrants because of inadequate flow or physical barriers to upstream migration caused by the dam structure itself.

d) Habitat loss impacts.

Habitat for spawning and rearing by wild and natural fish stocks is lost by inundation, severely fluctuating water flows and levels, migration barriers or insufficient base flows (rearing) during the low flow periods. Habitat downstream of a reservoir can also be affected by altered temperature regimes.

3.1.2 Wildlife vs. Reservoirs

Dam construction and reservoir filling create negative effects on wildlife that include inundation of floodplain habitat used by small mammals and furbearers for nesting, by ungulates and bears for feeding, and by carnivores for hunting. Raptorial birds (eagle, osprey and hawk) and piscivorous waterbirds such as mergansers, will be displaced to other areas where prey populations persist.

Reservoirs can provide new wildlife and bird habitat, albeit lake habitat that would support different species. Loons and grebes would prey on reservoir-resident fish, and ducks would utilize shallow areas if the water levels remained fairly constant during the breeding season. Large mammals generally do not benefit from reservoirs. However, small mammals and furbearers could use shoal habitat if the reservoir levels were controlled to create such areas.

3.1.3 Water Transport vs. Dams and Reservoirs

Dam construction can preclude the use of waterways past the facility for cargo vessel transport unless locks are constructed around the dam. Log driving past a dam can also be similarly affected. Reservoir filling and extremely low operational discharges can also impede vessel traffic and log driving downstream of the dam.

Benefits from reservoirs can be created for transportation activities downstream of the dam site if storage is available for flow augmentation during low flow periods when the river is too shallow for navigation or log driving.

3.2 Changes in Water Flow

Diversions for potable water and irrigation use result in less water being available for instream use. A reservoir can cause changes in the flow regime downstream of the dam or may not affect these flows except during filling if it is a run-of-the-river facility. Flow changes can also affect groundwater supply, which can affect upstream water users as well as fish habitat in the mainstem and the tributaries. The effects of flow changes on the instream values can be both negative and positive. Downstream uses affected include pollution management, fish and fishing, transportation, water-associated birds and wildlife, hunting and trapping, aesthetics and water-related recreation. The effects of flow changes on these uses are summarized as follows.

3.2.1 Pollution Management

Reduced stream discharges can increase pollution problems by reducing the quantities of water needed to dilute pollutants flowing into the system. The resulting increase in pollution levels has negative effects on all other instream uses below the pollution source. On the other hand, increased stream discharge can benefit pollution management programs by increasing the flows needed to dilute pollutants. The reduction in pollution concentrations is of benefit to all other instream uses and therefore pollution management needs for instream flows generally complement needs of other uses for instream flows.

3.2.2 Fish Production and Fishing

The effect of instream flows on the production of fish has recently received a substantial amount of research. Present day demands on instream water resources have required that more precise methodologies be developed to determine the instream flow needs of fish resources. Presently, over 20 methodologies have been reported in the literature that determine fish needs in different ways. Generally, low flows are limiting factors to fish habitat and fish production. High flows are also limiting because of the inundation of habitat, the high velocities and the redistribution of sediments that are caused by these high flows. Frequently, fluctuating stream flows can also create negative effects because of flooding by high flows, stranding because of very low flows, and redistribution of sediments at times of the year when high suspended sediments in the water column and sedimentation of channel substrate has detrimental effects on fish.

Because each fish species has distinct instream habitat requirements, the determination of adequate instream flows for fish resources depends on which species is to receive the priority for provision of suitable habitat by physical conditions. Figure III-1 shows that for three hypothetical species, the optimum habitat for each species occurs at three different flows. This is because each species has a specific range of flow velocities and channel depth that provide the habitat it needs for its various life stage activities. Controlling stream flows for the benefit of any one species can have negative effects on the habitat conditions of the other species. Sports fishing activities can also be significantly affected by changes from water flow. A more detailed discussion of methodologies for determining instream flow needs is given in section IV.

3.2.3 Water Transport

Waterborne transportation systems are affected by stream flow changes downstream of diversions or reservoirs. Reduced discharges can reduce channel depth and prevent navigation, and log driving and fluctuating discharges can cause redistribution of sediments and the creation of uncharted bars that can impede transportation. Reservoirs can benefit instream transportation by flow augmentation to provide the necessary depth for transport vessels and log booms.

3.2.4 Water-Associated Birds, Wildlife, Hunting and Trapping

Downstream of diversions and reservoirs, bird and wildlife populations can be benefited by the smoothing of natural flow fluctuations. Improved fish production can result from steadier flows and can provide increased food resources for fish-eating birds, such as mergansers. Steadier flows can also increase the quantity of

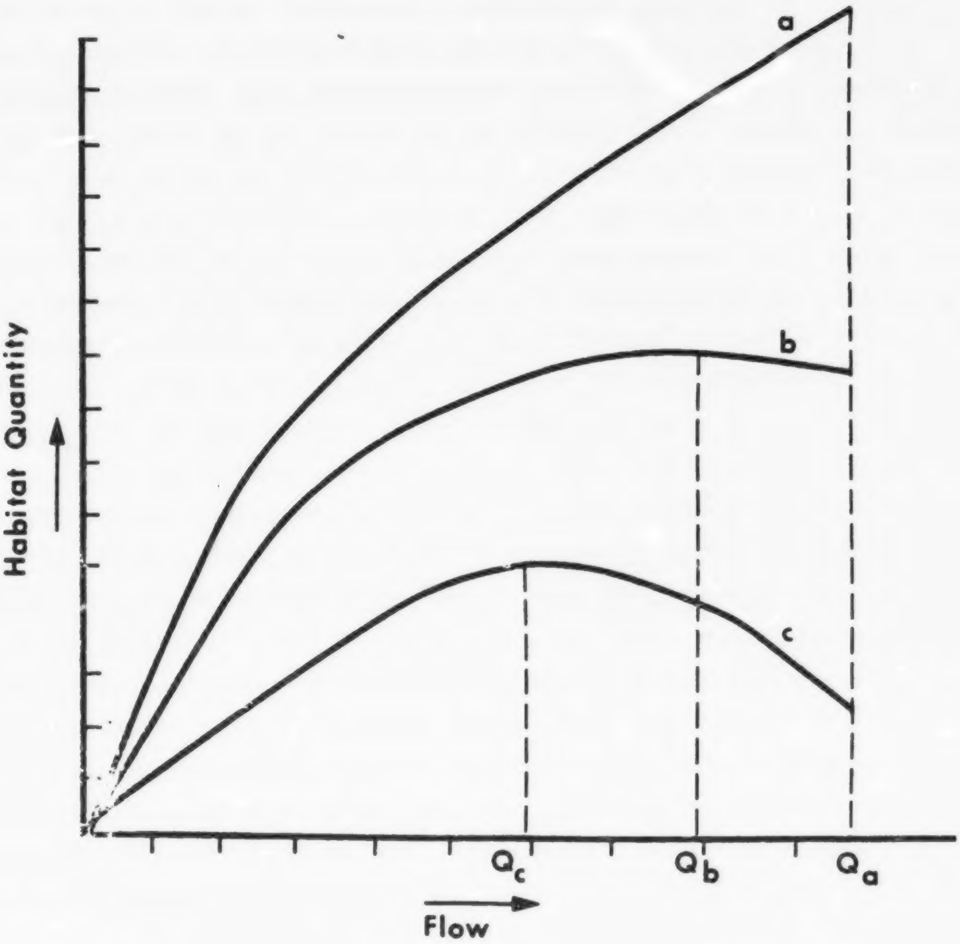

FIGURE III-1

Optimum flow (Q) for three hypothetical species (a, b, c).

nesting habitat in adjacent sloughs and marshes. More even flows improve channel stability, due to the establishment of bank vegetation which can contribute to improved bird habitat.

The effects of regulated flows could have negative effects on ungulates and both positive and negative effects on small mammals and furbearers. Ungulates could be deprived of food resources if flood peaks are removed. Flood flows that inundate valley floodplains stimulate the growth of new browse vegetation. Flood flows also redistribute channel sediments and create new bars and banks where new browse plants can grow. Shaving flood peaks can prevent new browse plant growth, reducing ungulate food supply. Another negative effect on ungulates can occur if low flow augmentation increases river discharge sufficiently to create excessive depths and velocities at traditional ungulate crossing areas.

Small mammal habitat can be increased by flood control. Beaver build dams on streams that have had high flows removed and muskrat inhabit marsh areas that are created by the sedimentation and vegetation encroachment that can occur under very even flow states. However, small mammals that inhabit floodplains can be adversely affected by frequent flow fluctuations that cause inundation, stranding and washout of dwellings and habitat. Flow fluctuations can have substantial negative effects in winter when ice, which normally would be fast on the river all winter, is broken out by high flows. Ice movement can damage overwintering habitat and create jams that increase velocity and cause bank and channel erosion. Flow fluctuations in winter can also cause increased ice thickness which, in turn, can cause increased habitat damage during break-up. Negative effects are also created by reduced flood flows in spring, which cause winter ice to remain longer than normal and delay the onset of spring.

Flow changes affect hunting and trapping through changes in bird and wildlife populations, as well as by altering the access to hunting and trapping areas. Trapping typically is a winter activity because access over frozen waterbodies is possible. Fluctuating flows can break-up winter ice and impede or prevent winter access to trapping areas.

3.2.5 Aesthetics

People's perception of attractive water scenes vary with the viewer (e.g. a fish biologist may like to see plenty of clear, clean water covering fish habitat; a water resource engineer might prefer the curving grace of a hydroelectric power dam spillway). However, Garn (1982) noted that the maintenance of aesthetic value involved incorporating design elements that minimized the amount of visual perceptible change.

3.2.6 Recreational Boating and Water Sports

Downstream of reservoirs and diversions, reduced discharge can create or reduce hazards for boating activities. In large rivers, motor boating can be impeded by the dangers of encountering, at high speeds, obstacles that were previously well below the surface. In smaller systems, hazards can be created for rowing, canoeing and kayaking. Higher flows during low flow periods can benefit these activities.

Swimming and related activities are affected by reduced flows through the reduction in surface area and depth of commonly used swimming places, through the drying of the channel at cutbanks where diving or rope swinging activities occur, and through increases in the difficulty of access to the swimming areas. High flows increase velocity and turbidity, inundate beaches, and reduce water temperature. Benefits that can accrue from flow changes include increased beach area and increased water temperature when high flows are reduced, and deeper, larger swimming areas when low flows are increased.

4.0 CONFLICTS BETWEEN INSTREAM USE AND LAND USE

4.1 Watercourse Shoreline Development

Demands for foreshore include the practical needs of industrial and transportation facilities, the aesthetic needs of residential developments, and the practical and aesthetic needs of recreational facilities. These needs conflict with the needs of instream values, including fish and fishing, wildlife, birds, hunting, trapping and natural aesthetics. Conflicts related to shoreline development can also occur within an instream resource use; for example, an anadromous trout stream enjoyed by anglers for its fishing and wilderness features, could be selected as a site for a major hatchery. The development of the site, the access to it, and the permanent presence of buildings and personnel, would conflict with the trout fishermen's needs for wilderness values on the system.

Industrial, transportation and residential developments all involve the clearing and filling of riparian land, removal of bank vegetation, and in floodplain areas, construction of protective dyking and rip-rap. Linear developments, such as roads, railways, and powerline rights-of-way, involve the altering of riparian and in-channel features at stream and river crossing sites. After construction, maintenance work sometimes is necessary to repair some damage. Dykes and linear projects also provide new access by people and vehicles to areas that had been undisturbed. Transportation facilities use both the riparian and shore zone areas, and include channel filling or pile driving that can change channel morphology, flow characteristics and sediment erosion and deposition. Bank and channel changes also can be caused by the development of marine ways.

Residential developments concentrate people in riparian areas, causing increased use of banks, bars and riparian woodlands. Recreational facilities, such as picnic sites, campsites, beaches and boat launches, developed for the convenience of instream uses, can cause changes to riparian bank and channel characteristics and, therefore, can conflict with the recreational needs for aesthetic and wilderness features.

Shoreline developments therefore can contribute to reduced habitat quantity and quality for fish, birds and wildlife, to decreased hunting, fishing and trapping values, to increased pollution and to decreased aesthetic values.

4.2 Agricultural and Forestry Operations

Agricultural and forestry activities that create conflicts with other instream uses include clearing riparian vegetation, stabilizing and protecting banks with rip-rap or other materials (e.g. used car bodies), allowing cattle access to the water for drinking, installing and operating stand pipes and pump houses for water withdrawal, driving trucks or cattle across fords and extending fences into waterbodies. These activities can conflict with instream use by fish, birds and wildlife populations through the removal of bank cover and damage to cover created by undercut banks and through the release of sediments into the water column. Fish are further affected by disturbance to spawning substrate and to invertebrate production habitat. Fishing is affected by the removal of local fish refuge and by the obstacles to access created by the fencing. Cattle ferries controlled by cables and cattle using fords impede the recreational boater, and the visual effects of fencing, water supply structures, bank protection and bank damage by cattle conflict with aesthetic expectations.

Floodplain agricultural and forestry development directly conflicts with wildlife and bird uses. Land clearing removes forest habitat and browse for ungulates and tall streamside trees used by raptorial birds for nesting. Land draining and filling removes habitat used by waterfowl and small mammals, particularly furbearers. Watershed logging reduces natural runoff storage and results in sudden flow changes through flash flooding. These effects in turn cause water quality and stream channel changes.

Agriculture also can conflict with pollution management objectives for instream water resources. Water withdrawal for irrigation and waste flushing can deplete water quantities needed for pollution and dilution, and agricultural runoff and waste discharges can contribute to increased water quality problems.

4.3 Flood Management Facilities

Flood control reservoirs and river channelization enable the use of downstream river channels in floodplain lands for developments and activities that otherwise could not occur in areas of periodic high flows and flooding. Flood control therefore can contribute to water use conflicts in that additional alternative uses can be made on the shoreline lands and instream resources. While flood control enables new industrial, transportation, residential and recreational uses on shoreline land, the operation of the flood control reservoir can have effects on other instream resources as outlined in subsection 3.1.

Flood control reservoirs can also create aesthetic impacts, including the unnatural barren appearance of the drawdown zone when the reservoir is less than full, and the visual impact of the sediment deposits in the river below the dam.

IV METHODOLOGIES FOR DETERMINING INSTREAM RESOURCE NEEDS

The most difficult of the instream resource needs to determine are those for the biological resources. Needs vary widely among species and with different times of the year. Taken in conjunction with the natural or man-made changes in flow patterns in different watercourses, the determination of how much water is really needed to support healthy resources is a very complex process.

To start the process of evaluating biological resource needs for a particular watercourse, biological resource managers must also establish a number of very definite management objectives and policies with regard to the particular watercourse in question. Foggy thinking about these objectives will lead to unclear directions for the data analyzers who are attempting to determine the actual needs of the resources in the river. This leads to frustration and an eventual likely rejection of the conclusions of any kind of objective analysis.

Since determining instream needs for fish is usually the most common and most complex problem in water resource allocation, this process will be used to illustrate the approach. The kinds of clear policy decisions which resource managers must make regarding a particular watercourse are indicated by the following questions:

1. Are fish resources important enough in the watercourse being considered to warrant a full instream fish resource needs analysis?

2. Are factors such as the sport, commercial or native fisheries, stream morphology sequences, or some other feature of the watercourse (e.g. water quality, physical substrate changes, ice formation, etc.) more limiting to the fish resource than just flow (depth and velocity) per se?

3. Have the fish species been properly priorized by importance for the stream in question?

4. Have the fish species life history stages been properly priorized by importance?

5. Have key locations for each species and life history stage been selected?

6. Have the correct parameters such as flow velocity, water depth, substrate type, temperature, cover, water quality, etc. been chosen as the ones which presently limit the resource?

7. Has ice formation or other seasonal factor, such as a need for flushing, being taken into account? Can it be controlled?

8. Is there adequate existing information on stream hydraulics from Water Survey of Canada or other sources to carry out an analysis of the fish resource instream needs? If not, can this data be synthesized from other cross-section data?

9. Are there adequate stream flow records to carry out a hydrological analysis (e.g. is the period of record long enough)? If not, can this data be synthesized?

10. Is there adequate fish habitat use data to carry out an analysis (e.g. is it known how fish are using the habitat in the specific stream being considered)? If not, can some of this data be extrapolated from other streams for use on the watercourse under consideration?

11. Is there adequate information on substrate, temperature and cover parameters to carry out the analysis? If not, can this data be synthesized to carry out the analysis?

Once decisions are made on these parameters by the fish resource managers, the data analyzers (computer operators, hydrologists, biologists) can begin work on actually determining the instream needs of the fish resources of a particular watercourse, and the limits to the resource that may be imposed by other uses of the water. The objective should be to establish a number of different fish resource maintenance levels which correspond to a number of different water management options. Establishment of the different levels of impact on the fish resource then allows water resource planners to determine the level of use for each water resource that shall be achieved in the overall plan of the water system.

1.0 TECHNICAL METHODOLOGIES FOR DETERMINING INSTREAM RESOURCE NEEDS

1.1 Determining Flow Needs

Instream flow need (IFN) assessment methodologies recently or now in use principally in the United States number over 20. Few formal methods have evolved to date in Canada. The originators of IFN techniques generally found it necessary to develop special procedures, based on or independent of other methodologies, in order to address unique aspects of the IFN problems before them. As a result, the purpose and scope of present IFN methods vary from general recommendations for flow needs throughout large geographic areas, such as river basins and jurisdictional regions, to highly detailed assessments of discharge-related changes in habitat quantity for selected species, in specific reaches downstream of existing potential impoundment or diversion projects.

Appendix I summarizes key descriptive information for 19 IFN methods. It does not include details on the procedures to be followed to carry out the methods, but is intended as an overview of the different methodologies presently in use.

The methods can be grouped into four broad categories, on the following basis:

Group I: "office" methods, using limited or no stream biological information and relying on hydrology records to recommend flow requirements over broad geographic areas;

Group II: stream-specific, hydrology-based methods that incorporate a set of cross-section data describing widths, depths, and velocities at a representative location;

Group III: stream-specific methods based on hydrologic data and several sets of hydraulic data;

Group IV: stream-specific methods based on hydrologic data, hydraulic modelling, and habitat weighting coefficients that reflect the relative suitability of component factors that contribute to habitat quality.

The choice of an appropriate methodology for a Canadian IFN assessment will depend on specific criteria and a variety of variables that cannot be fully considered in this report. To expand upon the information provided in Appendix I, a representative method from each of the four general groups was selected. The four methods are listed below, with brief notes on the rationale for selection.

Group I: Montana Method

- very common usage
- well documented
- basic technique, easily implemented
- broad application
- quickly provides interim recommendations for protection flows in situations where more detailed study is needed but cannot be done immediately.

Group II: United States Forest Service R-2 Cross Method

- only method relying on single set of cross-section data
- minimizes field work; relies instead on computer modelling (IFG-1, SCSIFM).

Group III: Water Surface Profile Method

- compares habitat at various flows
- uses hydraulic modelling (IFG HABTAT) to determine habitat quantity
- hydraulic data at only one discharge is sufficient for model calibration.

Group IV: Instream Flow Incremental Methodology (IFG-4)

- comprehensive method that considers hydraulic and hydrologic data in relation to species-specific habitat criteria
- detailed iterative methodology highly regarded for evaluating the effects of water development projects on habitat quantity.

1.2 Montana Method (Tennant Method)

1.2.1 Overview

The Montana Method was first documented by Tennant (1976). It is frequently used by various agencies for IFN determinations (Loar and Sale 1981). Consistent results were reported from testing the method "on 11 streams in Nebraska, Wyoming and Montana, while similar analyses were applied in 21 different states over a 17 year period" (Ott and Tarbox 1977).

The Tennant Method, in its original form, was not an IFN assessment method, but a set of guidelines for setting IFN flow regimes. It was designed to quickly but roughly determine flow recommendations on a regional basis, for protecting instream resources downstream of new or potential projects. The method was not intended for setting flows on a species or site-specific basis.

The method recommends discharges for several levels of instream resource protection, generally by reviewing published discharge data to determine average annual flow, and setting protection discharges as percentages of the average annual flow. No field work is required unless flow data are lacking, in which case, observations and photographs are required at various estimated discharges. The method is popular for broad IFN determinations, interim protection during more detailed study, or establishing permanent flow regimes in watercourses where the modest value of instream resources do not warrant the undertaking of an expensive IFN field program.

1.2.2 Limitations and Modifications

The advantages of the Tennant method include its simplicity and its minimum requirements for manpower, data and costs. It functions well as a quick, inexpensive means of assessing stream flow requirements for reconnaissance or planning level studies (Tennant 1976).

The method has several limitations, as follows:

1. It provides only a gross determination of protection flows.
2. It uses flow data directly and does not accommodate unusually extreme flows unless additional field work is done to make appropriate observations and measurements (Wesche and Rechard 1980).
3. The method does not quantify the effects of flow changes on habitat quality.
4. It requires a long period of record for flow data.
5. It does not consider the influence of channel morphology (Bayha 1975).
6. It uses mean flow. Median flow more precisely indicates central hydrologic tendencies (Loar and Sale 1981).
7. The method does not apply well to systems with constant (e.g. spring fed) flows or deeply incised or highly braided channels.

Several modifications (outlined below under Technical Procedures) were suggested by investigators after testing the method. Bayha (1978) developed an equation that better quantified the various flow inputs and outputs of a system that includes storage, diversions or groundwater use (Wesche and Rechard 1980). Tessman (1980) recommended several changes that enabled the method to account for the ecological importance of natural flow periodicity and the benefits of extreme fluctuations (Wesche and Rechard 1980). These additional considerations require not only that the method incorporate biological information for the system, but also that more highly qualified personnel participate in the work.

A modification using percentages of average monthly flows instead of average seasonal flows, at least in summer, could make the method more applicable for use in Canada. However, the seasonal needs of offstream water users and life history needs of instream fish resources should be assessed on a system-by-system basis to determine if this modification is beneficial. In most cases, because of winter flow needs of fish resources, the low winter flow regime can be determined by the average winter flow in each system, rather than average monthly flows in winter.

1.2.3 Information and Expertise Requirements

The method requires stream flow data from gauge records (e.g. Water Survey of Canada) or from discharge simulation (Ott and Tarbox 1977). A 10 or 20-year period of record is necessary. Very little manpower is required. Discharge records for Canada stream flows should contain sufficient data, including mean flows in many cases.

The initial phase of the method requires moderate expertise to review flow data and calculate the percentage discharges. Qualified, experienced personnel are required to more carefully justify or, if necessary, modify the flow recommendation.

1.2.4 Technical Procedure

The Tennant method makes IFN recommendations, based on fixed percentages of the average annual discharge. The table below summarizes the percent flow recommendations as they were originally developed (Tennant 1976):

Instream flow regimens for fish, wildlife, recreation and related environment resources.

Narrative Description of flows*	Recommended Base Flow Regimes Oct.-Mar.	 Apr.-Sept.
Flushing or maximum	200% of the average flow	
Optimum range	60%-100% of the average flow	
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe degradation	10% of average flow to zero flow	

* Most appropriate description of the general condition of the stream flow for fish, wildlife, recreation and related environmental resources.

Tennant (1976) suggests that recommendations for controlled flows can be checked by observing and photographing key habitat areas during a series of discharges released from the control structures, and by studying cross-section data collected by the water resource survey agency. From this work, the flow recommendations can be refined to more closely "mimic nature". Substantial judgment is required to "recommend the most appropriate and reasonable flow(s) that can be justified to provide protection and habitat for aquatic resources" (Tennant 1976).

1.3 U.S. Forest Service Region 2 Single Cross-Section Method (R-2 Cross Method, Colorado Method, Critical Area Method, Sag-Tape Method, IFG-1 Method, SCSIFM)

1.3.1 Overview

Region 2 of the U.S. Forest Service, which encompasses Colorado, Nebraska, South Dakota, eastern Wyoming and parts of Kansas, developed R-2 Cross to predict hydraulic characteristics at discharges for which hydraulic data were not available (Loar and Sale 1981). It was modified (Milhous 1978) to evaluate discharge-related changes in aquatic habitat.

The method requires that cross-section data be obtained from a Critical Area of the stream, which is an area that characterizes a typical reach, or which represents critical minimum habitat (Wesche and Rechard 1980). Hydraulic modelling enables depth, velocity and wetted perimeter to be calculated at different discharges. Cross-section width is weighted, according to the habitat suitability of the average velocity at specified depth intervals. Habitat quantity is calculated by multiplying the weighted stream width by 1,000 ft to give weighted area. A habitat discharge curve is then constructed, and appropriate flows are selected to provide the necessary levels of IFN protection (Loar and Sale 1981).

The method is suited for use on wadable streams for which there is a substantial period of recorded flows. Wesche and Rechard (1980) indicated that it applies to salmonid species in Rocky Mountain trout streams.

1.3.2 Limitations and Modifications

Two alternatives can be used for hydraulic modelling: the stage-discharge relationship, or the Manning equation. The use of the Manning equation avoids the need for more than one visit to the site, but careful consideration of the value of Manning's n is required when adjusting for high and low flows (Loar and Sale 1980). Formulae for determining Manning's n are being developed and tested by USFS, Region 2 (Wesche and Rechard 1980, from Lee Silvey pers. comm. 1980).

The use of Manning's n can be avoided by using a stage-discharge relationship to predict water levels, but this procedure is much more field-work intensive, requiring additional work establishing the first transect, and several visits to the site to collect a series of stage-discharge measurements.

The method overlooks unique needs of certain species. A test of the method, comparing it to IFG-4 method recommendations, showed that it provided critically low habitat for Colorado squawfish, while providing near optimum conditions for channel catfish (Prewitt and Carlson 1977).

The success of the method depends on the correct selection of the Critical Area and the cross-section transect (Prewitt and Carlson 1977). A large, more reliable data base can be developed by obtaining cross-section data from several critical areas, at several discharges, but additional costs are incurred (Wesche and Rechard 1980).

The method applies to all species, but only in small (wadable) streams.

1.3.3 Information and Expertise Requirements

A good understanding of the biophysical characteristics of the stream reach is required as the basis for the IFN assessment. The degree of effort for collecting the necessary information will depend on available manpower and funds.

An expert biologist is required to survey the reach, select the critical area and locate the transect site, as well as to apply judgment to the IFN recommendations made by the study to evaluate their validity.

An estimate of the manpower requirements to employ the R-2 Cross Method was provided by Wesche and Rechard (1980) as follows:.

	Field	Office
Number of persons	2	1
Number of man-days	1	1-3

1.3.4 Technical Procedure

A thorough synopsis of the R-2 cross procedure was prepared by Wesche and Rechard (1980), quoted in its entirety as follows:

> "The Critical Area approach to establishment of instream flow consists of using an interdisciplinary field team, each member of which makes a determination of the flow needed to maintain desirable qualities for his discipline. The field techniques used are as follows:
>
> 1. After extensive office study of maps, water diversions and basic data available on the selected stream or reach, the field team (consisting of a hydrologist, biologist, landscape architect, water quality specialist, and anyone else as needed to provide input where instream flows are important for other uses) tours the study area.
>
> 2. Each team member identifies, by visual observation, certain areas (Critical Areas) on the reach which would be most useful to him for studying the parameters important to his disciplinary use for instream water. These Critical Areas contain the limiting factors for streamflow for a particular parameter in that stream reach. It is assumed that if conditions are sufficient for each parameter at the Critical Area, they will also be sufficient at all other areas represented in the reach. Normally, the critical fisheries area is considered to be the shallowest cross section of the shallowest riffle in the reach being investigated.

3. The Critical Areas are marked and photographed.

4. Cross-channel transects are established to represent each Critical Area, and a cross section profile, consisting of depths and velocities at regular intervals, is measured. A master reference point is established upstream from the study reach and stage determined.

Office methods consist of the following:

1. Conduct a preliminary literature review and detailed study of the reach under investigation.

2. After the field investigation, the cross section data are applied to Manning's formula to synthesize the flow in the channel at various levels.

3. Based on the various synthesized flow levels, each discipline specialist identified the absolute minimum flow at each Critical Area need to meet minimum criteria for the parameters represented. Following this, he determines an optimum flow in the same manner. For Fisheries criteria, the State of Colorado (Kochman, pers. comm.) uses the flow which (1) wets 50 percent of the total bank-to-bank perimeter; (2) maintains a mean velocity across riffles of 1.0 to 1.5 feet per second; and (3) maintains the following depths:

   0.2-0.4 ft for streams 20 feet wide; and

   0.5-0.6 ft for streams 20 feet wide.

The recommendation is then "custom-fit" to each stream to meet at least one, two or all three of the above criteria. These criteria have worked well for coldwater fisheries but should not be applied to warmwater situations.

4. Determine seasonal variations in flow needs for fisheries, aesthetics, and other purposes.

5. Flows determined for Critical Areas are then related to a stage at a master reference point. This relates all Critical Areas to one stage-discharge relationship.

6. Present a package including range of flows for various parameters related to fishery, aesthetic and other instream flow users to the administrator."

1.4 Water Surface Profile Method

1.4.1 Overview

The Water Surface Profile (WSP) Method is based on a computer program developed by the U.S. Bureau of Reclamation to model hydraulic conditions and predict water surface evaluations downstream of dams (Loar and Sale 1981). It uses the Manning equation and cross-section data from one transect to make the hydraulic predictions (Horton and Cochnauer 1980). Because of these features, it was modified for IFN studies for fish resources (Wesche and Rechard 1980).

The WSP method is similar to the R-2 Cross Method, but is more sophisticated. It predicts depths and velocities longitudinally through the stream reach. Flow recommendations are based on the amount of habitat predicted by the inflection point on a habitat-discharge curve. It applies to salmonid species in small (wadable) streams.

1.4.2 Limitations and Modifications

The WSP method, on its own, does not predict habitat in relation to discharge; however, when used in conjunction with the Incremental Habitat Analysis program called HABTAT or IFG-3, it provides the hydraulic predictions necessary for HABTAT to determine habitat area (Horton and Cochnauer 1980).

An advantage of WSP is the requirement for only one set of calibration data. This is made possible through the use of the Manning equation, which makes calibration "by adjusting roughness coefficients (Manning's n) until the water surface elevations predicted by the computer approximate those measured in the field" (Horton and Cochnauer 1980). However, a problem is encountered when using the selected values of n; the difference between predicted evaluations and velocities and measured values increase with flows that are greater or lesser than the calibration flow (Horton and Cochnauer 1980).

Other limitations of WSP are as follows:

1. An inflection point is not always evident on the habitat discharge curve. If more than one transect is used, it may be difficult to define an inflection point (Nelson 1981). Also, channel shape influences how evident the inflection point will be (e.g. it may be difficult to determine for a U-shaped channel).
2. The inflection point on the habitat discharge curve, used to determine flow recommendations, is not necessarily directly related to the habitat requirements of aquatic organisms (Prewitt and Carlson 1977).
3. It does not incorporate species habitat criteria (Wesche and Rechard 1980).
4. It can involve large manpower expenditures (Wesche and Rechard 1980).
5. It does not apply to large streams or rivers.
6. It was designed only for salmonids. It was used to predict Colorado squawfish habitat, but it provided critically low habitat for the squawfish; at the same time, providing nearly optimum conditions for channel catfish (Prewitt and Carlson 1977).

1.4.3 Information and Expertise Requirements

For the WSP program, the field data need to include water surface elevations in addition to cross-section depth and velocity measurements. A biologist is required on-site to locate the most representative transect site. A three-man crew should be able to survey five cross-sections, if desired, in one day (Prewitt and Carlson 1977). Horton and Cochnauer (1980) reported that implementing the WSP required 22 man hours of a three-man crew, with the time being allocated as follows:

4% - planning
55% - field surveys
18% - data processing
23% - analysis and interpretation

Good access to the stream is assumed in generating these figures.

1.4.4 Technical Procedure

The following summary of field survey requirements is taken from Stalnaker and Arnette (1976):

1. Cross-section transects. These may be measured in the manner described for the Tight or Sag-Tape Method, with the number of partitions across the transect not to exceed nine.
2. Distance between cross-sections (transects).
3. Measured discharge in cubic feet per second, if gauging station data are available, otherwise use transect data to compute discharge using $Q = V \times W \times D$.
4. Water surface elevations at all cross-sections.
5. Description of the stream bottom at each cross-section.
6. Description of bank and overbank material and vegetation.
7. Identification of points where streambed material, vegetation, and streambank change within the cross-section.

When field data collection is completed, the individual cross-sections should be plotted. The scale used is not particularly important. These plots should include identification of streambed material, types of vegetation on overbank, and left and right streambank identification.

The output data of the WSP program were summarized by Stalnaker and Arnette as follows:

> "Available output from WSP includes specific data for each cross-section and tabular summaries of data for all flows included. Specific cross-section output includes water surface elevations, flow velocities, tractive force (amount of force exerted upon stream bottom), conveyance areas and widths, hydraulic radii, and discharges. The predicted values are based on and within the precision of the field data.
>
> From the output data, a water surface profile showing water surface elevations, thalweg, and cross-section location (by station) is plotted. A rating curve for the most downstream section is also plotted.
>
> By the incorporating of fish species depths [and] velocity criteria, instream flows can be assessed."

1.5 Instream Flow Incremental Methodology (IFG-4 Method)

1.5.1 Overview

The incremental methodology is a detailed iterative process for evaluating the quantity and quality of instream habitat at different discharges. It was designed to provide resource managers and instream flow negotiators with the means to determine the amounts of habitat change that would occur with given changes in discharge (C. Stalnaker pers. comm. 1982). In general, it can be adapted for use for most species, but it was not designed for large streams that cannot be waded. It was not designed as a method to determine discharge recommendations. The incremental methodology "allows quantification of the amount of potential habitat available for a species and life history phase, in a given reach of stream, under different stream flow regimes with various channel slopes and configurations" (Wesche and Rechard 1980). The method involves the following four main components (Wesche and Rechard 1980):

1. computer simulation of the hydraulic conditions of the stream channel;
2. determination of depths, velocities, or other pertinent characteristics present within the channel area being studied;

3. determination of weighting factors that indicate the relative utility of the various physical characteristics as components of fish habitat;

4. determination of the amount of stream channel area that provides fish habitat, using weighting factors to reduce the value of increments of habitat area that are less than fully suitable.

1.5.2 Limitations and Modifications

The incremental methodology is a powerful, widely-recognized procedure for quantifying the effects of flow change on habitat quantity. It is a detailed, time-consuming process (Horton and Cochnauer 1980) that requires special expertise in fish biology, hydrology, and data handling for computer programs, and greater expertise in evaluating the results of carrying out the methodology, to make judgments and recommendations for flow regimes.

Specific limitations include the following:

1. The HABTAT program, which determines the value of habitat increments in relation to accepted species preferences, requires that accurate species and site-specific preference criteria be used. Using velocity and depth criteria drawn from different geographic areas and instream environments, and varied literature review on field methods, "has led to generalizations that may not be applicable to every study reach. Most information gathered has been taken from collections in small wadable streams and may not be applicable to large streams" (Horton and Cochnauer 1980).

2. The hydraulic simulation process requires that limits be set on the discharge regime used for the simulation, if only one set of cross-section data is available to calibrate the model. Additional calibration data for different discharges provides greater prediction accuracy (Bovee pers. comm. 1982).

3. The calibration of weighted usable area (WUA) requires the use of a weighting factor to indicate joint suitability of habitat parameters. The joint suitability is the product of individual suitability factors (i.e. for depth, velocity, substrate, cover, etc.). The calculation of joint suitability assumes that the component factors are independent of each other (Loar and Sale 1981; Lincoln Pearson pers. comm., Oregon Department of Fish and Wildlife 1983). The assumption is valid if the "frequency analyses of habitat selection data collected from a wide range of available habitat conditions...reflect a natural integration of the relative importance of each parameter" (Geer 1980). The relative importance of each parameter would be significant if a species exhibited substantial preference for values of one parameter, and little or no preference for values of another.

4. The incremental methodology does not produce a flow regime recommendation. It relies on the expertise and judgment of professional biologists to evaluate the results of the method's computations to arrive at acceptable discharges.

5. The method does not function well on streams with uniform flows, such as spring-fed streams. To calibrate the IFG-4 model, transects are required at two or three representative discharges, which would not be possible on steady flow streams (Geer 1980).

6. The computer simulation of hydraulic features is difficult under conditions of low flow, heavy weed growth, shifting channel or ice cover.

1.5.3 Information and Expertise Requirements

Critical impact data include long-term discharge records and accurate habitat preference criteria for the important species present in the system. For initial study planning, the methodology requires sound information on the distribution and abundance of important species, and an understanding of the general effects of proposed flow alteration projects on instream habitat.

Throughout the study, a highly-qualified biologist should be involved, to ensure that cross-section data are representative, and that the results of the various model predictions intuitively make sense (W. Geer pers. comm. 1983).

Geer (1980) found that to carry out the incremental methodology on Utah streams, the study required between 85 and 170.5 man-hours per study section (method application); 44 to 77.7% of this time spent on field work. Equipment outlay amounted to $4,200.00-$4,350.00.

1.5.4 Technical Procedure

The four main steps of the methodology were described briefly above. Additional details are provided here from Stalnaker 1978:

Step 1. Stream Channel Simulation

Use several cross-section transects, subdivided into 9 to 20 subsections, to develop data base upon which computer program can predict hydraulic parameters. Use various potential discharges to run the computer model to predict mean depth and velocity at each stage.

Step 2. Habitat Area Calculation

Calculate the area of the subsections in which different depths and velocities occur (area = width of subsection x 1/2 distance to next transect).

Step 3. Habitat Suitability Calculation

Determine habitat suitability, or weighting factors, for the hydraulic parameters being considered (depth, velocity, substrate, etc.) and calculate a composite or joint suitability factor by multiplying together the individual parameter suitability factors.

2.0 DETERMINING WATER QUALITY PARAMETERS

A great deal of research has gone into establishing instream resource needs related to water quality parameters. This research is continuing and the parameters are becoming better refined as more knowledge is gained. Parameters have been established for most kinds of pollutants or water quality change which could take place in the freshwater systems in Canada.

Many situations where water quality has been changed, to the detriment of the instream resources in the past, are in the process of being corrected, such as in the Great Lakes and in areas downstream from particular industrial plants in other parts of Canada. Problems such as acid rain and multiple pollution source effects on instream resources still exist, but most situations can be cleaned up if the political will exists to do so. It is generally agreed in Canada that there is enough legislation and technical know-how to solve most water quality problems in the country. The same cannot be said of water quantity allocation problems. A full discussion of water quality issues would be a report in itself, therefore extensive detail on this subject is not presented here. Specific information related to effluent and water quality standards in Canada is contained in the legislation and regulations outlined in Appendix II.

Since water quality parameters are significantly affected by water flow, some of the methodologies that were developed for determining instream resource flow needs could also be used to establish water quality protection requirements.

3.0 SPECIAL CONSIDERATIONS IN DETERMINING SOME INSTREAM RESOURCE NEEDS

Other instream resource uses of water resources pale in significance to those of fish resources in most small to medium-sized watercourses. Many other instream use needs are much more easily determined than fish resource needs in that specific depth, flow, water quality and temperature needs can be established with relative ease for recreational boating, aesthetic qualities, wildlife and transportation use. Indeed, in most cases in the United States, it is assumed that once fish needs are taken into account, other stream resource use requirements will be adequately satisfied.

Obvious exceptions to this general rule are that transportation and boating needs may require deeper water at different times from the fish, potable water supplies may require higher water quality than fish, and aesthetic requirements may dictate that, in fact, stream flows be allowed to fall to very low levels to make stream bottoms show through the water surface. Specific aesthetically attractive points on the other hand, such as waterfalls, may require an increased flow at certain times of the year to correspond to maximum tourist travel.

Many of the same methods outlined in previous sections for determining fish resource needs can also be adapted for determining instream flow needs for other activities and resources on a watercourse (Tenant 1976, Walsh et al. 1980). Hyra (1978) described two mechanisms for doing this, the single cross-section method and the incremental methodology, to determine instream flow needs for recreation.

Specific recommendations related to which methodologies should be adopted for use in Canada are listed in the Conclusions and Recommendations sections of this report.

4.0 COMPARING INSTREAM RESOURCE NEEDS AND VALUES WITH OFFSTREAM RESOURCE NEEDS AND VALUES

4.1 Establishment of Instream Resource Values

Industrial instream resource uses are quite easily quantified in economic terms and have been in many areas. There is very little basic information in Canada on the values of most non-industrial instream resource uses. Most studies are either local in scope, or the information is outdated. Much more work is required in the area of documenting the actual biological resources use of water, recreational use of water systems, and the role watercourses play in contributing to the aesthetic enjoyment values of Canadian life. Many of the resource uses which are considered very valuable in the minds of Canadians in some intangible way, do not lend themselves to actual economic quantification.

Although economists have attempted to overcome this problem by assigning dollar values to the perceived value of an individual's ability to undertake a certain fishing or recreational experience, for example, this approach has met with mixed results. The actual numbers which are generated are looked upon with some scepticism by industrial developers of water uses and the biological and recreational-oriented interests alike. Since a radical new breakthrough in quantifying the value of many instream resources is unlikely in the near future, it would appear that a pragmatic approach for dealing with these values would be as follows:

1. Instream values, where measurable in economic terms such as landed fish prices, fishing and hunting recreational expenditures, tourist facility values, etc., should be measured as accurately as possible and these figures documented and regularly updated in technical publications.

2. Public values put on instream resources in many areas and the perception of public values of these resources require clarification and accurate documentation. One might find considerable variation across the country in the values

that the public put on instream resource use experiences. Residents of Campbell River, British Columbia may value the fishing experience more highly than going to a restaurant, for example, whereas urban dwellers in Montreal, Quebec may put a higher rating on the latter. These regional differences should be documented and explained wherever possible.

3. Any proposal to develop water uses in Canada for further instream or offstream resource development should be subject to a thorough public review process where federal resource interests or jurisidictions apply. This could be an Environmental Assessment Review Process (EARP) style process, or a more legalistic approach, depending on the type of development being contemplated and the terms of the water right, water licence or simply the water use being applied for. A screening mechanism, similar to the EARP process within Environment Canada, could be set up to evaluate different water use applications to decide which ones were large enough, or had a large public interest component, to put through an entire hearing process. To make the public hearing process meaningful and to permit public interest groups to participate fully, these groups should be funded by the hearing process, either by the proponent or by the government.

4. The allocation of water for instream and offstream use should be a dynamic process. Water development agencies and companies should be required to file 5 or 10-year water use plans, which would be public documents, available for review. Acceptance or renewal of the plans would be given by Environment Canada after provision for public input. In addition to this process, water rights awards and water development facility licencing should be subject to a regular review process. Although it is recognized that water rights are presently perceived as property rights in Canada, and that water use facility licencing is presently done on a permanent basis because of the long-term nature of the facilities being constructed, a change in these procedures is required to enable changing public values and water use values with time. Radical short-term changes in water right allocations and water use facility licencing is not contemplated by this dynamic process. However, a gradual

phasing-in of water use changes and reallocations is necessary in many past projects in Canada and will be even more necessary in future as water resources run short in many areas.

This reallocation of water uses is presently underway in the United States, particularly in the west where water resources are over-allocated and instream environment perceptions are high.

4.2 Optimizing Instream and Offstream Water Resource Use

A few computer programs presently exist which attempt to model the instream and offstream resource needs and values for watercourses. These models at present have been developed for mainframe computer systems, but with the advances in the desktop type computer hardware, similar models are being constructed to run on these less expensive machines.

Once these models are constructed for use in desktop machines, they will be much more generally available to a variety of resource managers and planners, including all types of instream resource planners and offstream resource proponents. Thus, the manager of fish resources, for example, will have available to him at very little cost and for very little effort, the model which will contain the needs and values of, say, hydroelectric and irrigation resource uses, as well as his own instream fish resource use of water, available from a particular watercourse. He can then try out a number of management and allocation options on his own machine to determine how easily his particular requirements for the maintenance of the fish resource can be accommodated by other water users. More important, an instream or offstream resource manager could likely determine where the point of inflection would be for another resource manager in terms of where unacceptable levels of impact would occur. This capability should significantly increase the knowledge level and appreciation for multiple users of the water resource.

5.0 MAKING A MANAGEMENT OR POLITICAL DECISION

With the addition of new technology and new methodologies for establishing instream resource needs for parameters such as flow and water quality, decision options should be clear at the water resource management level. Decisions will often be necessary to balance or trade-off different levels of resource values with others.

Water resource managers and elected politicians will have to make these decisions on which course to follow, based on factors such as the financial resources available, perceived priorities of society, and local needs of minorities for the water basin in which new water allocations are being considered.

V PROTECTION OF INSTREAM RESOURCE VALUES

1.0 CANADIAN FEDERAL, PROVINCIAL AND TERRITORIAL LEGISLATION AND ADMINISTRATIVE ISSUES

Federal legislation having specific applicability to the protection of instream resources is summarized in Appendix II. At least three main conclusions can be drawn from a review of this legislation. They are:

1. Almost all the laws, regulations and standards have to do with water quality and physical habitat protection in watercourses. Very little of the legislation relates to water quantity management.

2. There appears to be a concensus in Canada that there is enough legislation in place to adequately manage water quality and physical biological habitat in watercourses. Most deficiencies in ensuring the protection of instream resources from unacceptable impacts in these areas are the result of the lack of administrative or political will in enforcing the provisions of the legislation.

3. There are large areas of jurisdictional overlap and duplication in federal-provincial and federal-territorial instream resource water quality protection legislation in Canada. This legislative overlap also results in extremely inefficient duplication of administrative staff applying the legislation. Indeed, environmental agencies have proliferated in Canada since the 1960's, and in many cases they spend much more time meeting with each other to sort out jurisdictional disagreements and roles than working on resolving the real instream resource protection problems at hand. This is not only inefficient, but also counter-productive, and in the end, less instream protection is achieved.

What is required, therefore, is a major revamping of federal water quality management agencies to significantly curtail their activities and staff in areas where they are no longer required to protect instream values. Particular federal government agencies where large federal resources are no longer required because of delegation of most environmental management responsibilities to the provinces and territories, include the Environmental Protection Service of the Department of the Environment nationally, Department of Fisheries and Oceans in the Yukon and Northwest Territories, prairie provinces, and the Renewable Resources Branch of the Department of Indian and Northern Affairs in the territories. Water quality-related functions presently being carried out by these agencies could be transferred to provincial or territorial counterparts. Necessary federal water quality responsibilities could be returned to the Department of Fisheries and Oceans.

Water quality monitoring programs presently carried out by the Inland Waters Directorate could be significantly curtailed without important losses in instream resources water quality protection. Inland Waters capability in monitoring stream flow hydrology and carrying out stream channel cross-section hydraulic surveys should be significantly increased, however, to ensure this data is available when long-term water management decisions are made in future. Federal government research into water resource allocation questions should be increased. A greater decentralization of federal government water management agency personnel from Ottawa to the regions, and in the regions to administrative districts, would bring staff members closer to the actual instream protection problems in the field and ensure good local liaison with provincial and territorial agency personnel.

2.0 CLASSIFICATION OF CANADIAN FRESHWATER SYSTEMS

A classification system for watercourses in Canada is required, preferably with an inter-agency agreement. If this were initially possible just within an agency, it would be useful. At present, water resource developers have little guidance before feasibility studies for a project are begun to identify what type of instream resource conflict problems might require resolution. Instream resource management agencies tend to be noncomittal on their positions regarding the importance of various stream and river systems. This leads to the instream resource management agencies being reactive and largely negative to development proposals. There is a wide range in instream and offstream resource values in watercourses in Canada and this should be reflected in the classification system. Such a system, much like the Canada Land Inventory, which has been done for land capability, could include the following components.

2.1 Heritage River Designation

The Canadian Heritage Rivers System (CHRS) is a process set up under the responsibility of Parks Canada for designating important rivers in Canada to be preserved for the enjoyment of their natural and human heritage and for their future recreational enjoyment and heritage appreciation. Three criteria are used to determine heritage value:

- natural heritage of outstanding Canadian value
- human heritage of outstanding Canadian value
- the provision of recreational opportunities of outstanding Canadian value.

The implementation of CHRS is being undertaken by the Canadian Heritage Rivers Board, which is comprised of members of the federal, provincial and territorial governments.

2.2 High Priority Fish and Wildlife Resources Rivers

Fish and wildlife resource management agencies are very reluctant in Canada to classify any system as having low importance for aquatic or water-related fauna.

In the present world of increasing conflicts for water use, this position is unrealistic, and in the long run, not conducive to the best protection of resources. One should not write-off or destroy small populations or species of low economic importance if practical solutions can be found to protect them. However, it is reasonable to expend more research and management effort in protecting the most important fish and wildlife resources, hence the need for a classification system to priorize their importance in local, regional and national contexts. If such a system were in place, proponents for other water uses on a watercourse could then know at the start of a project feasibility process, the level of effort required to resolve conflicts with fish and wildlife resources.

2.3 High Priority Other Instream Activity Rivers

Watercourses having high recreational boating, water sports, water transportation, historic and aesthetic values should be so classified.

2.4 High Priority Offstream Water Use Rivers

River systems considered to have high potential for offstream use such as hydroelectric power development, good potable water supplies, or irrigation sources should also be priorized and classified. Other water resource managers and the public will then be better prepared to assist in water allocation decision processes when they are necessary.

2.5 Zoning Watercourses for Certain Instream or Offstream Uses

As water use conflicts and competition among water users intensifies, multiple use of the resource in its fullest sense will become common. Thus, potable water, hydroelectric and fisheries resource developments could take place using a common dam. A river could be considered a potable water supply and its watershed protected at its source, but could be used for pollution disposal, irrigation and transportation further downstream. Classification systems should reflect some different zoning for water use capability at various points along a watercourse.

3.0 WATER MANAGEMENT BY RIVER BASIN

Water management to date in Canada has been carried out largely on a regional, provincial or national scale. Thus, monitoring and water quality standards have been established for these large, usually politically-bounded, areas. There is some merit to having water quality and instream resource habitat protection standards applicable to large political areas. The policy is to prevent the formation of pollution havens where industry can escape applying measures to control pollution and instream habitat impact mitigation.

To some extent, this policy has been successful in that most industry in Canada has installed pollution control measures and/or are on a schedule to clean up their effluent. However, it is unrealistic to believe the St. Lawrence River downstream of Montreal can be a Miramichi in terms of water quality. The St. Clair River in southern Ontario will never be a recreational fishery system like the Dean River in British Columbia. Therefore, in addition to a river classification system, what is required is a stronger river basin-oriented way of managing water in Canada's watersheds. This is particularly required if water quantity allocation is to be done in the best public interest.

Using the present federal effluent standards and instream habitat protection provisions as base levels for instream resource protection, additional basin-specific water quality and habitat protection standards can be used where necessary. Each river basin requires assessment on its own merits for determining water quantity allocations. Such allocations will require a combination of local water resource values, basin classification, local water needs, water economics and technical capability to be taken into account. There are at present in Canada a number of water basin management boards (e.g. Okanagan Basin Management Board, Prairie Provinces Water Board, and the Water Board of the Northwest Territories). A number of temporary study investigations have also been conducted on large basins such as the Mackenzie, Churchill-Nelson and Saint John River. However, these were short-term administrative bodies. Long-term river basin management agencies with secure budgets and legislative mandates are required.

4.0 ESTABLISHMENT OF BASELINE DATA GATHERING ACTIVITIES RELATED TO DETERMINATION OF INSTREAM RESOURCE NEEDS

There are three main components to establishing instream resource needs for biological resources, recreational activities, and industrial uses. Data on all three components are required before a thorough and reliable water allocation scheme can be designed.

Data is required on the hydrology of a flowing system, the hydraulics of the stream channel in which the water flows, and the use the instream resources make of the watercourse in question. The latter component is fairly easily defined for industrial and recreational uses, but is very complex for biological resource use.

Many hydrometric gathering stations are established in Canada at the present time and, generally, a good data base exists on hydrology matters in most major river systems. This is fortunate because this data requires many years of compilation before a sufficient statistical base is established to make it reliable. However, many systems in Canada which are presently contemplated for water resource use projects, do not have water flow measuring stations on them and this data must be synthesized from adjacent systems and from local terrain and rainfall records. This is accurate enough for planning purposes, but is not accurate enough to actually design a water use development project and properly allocate water resources of a system for multiple use. More hydrology data should therefore be gathered, and since this information requires considerable lead time to make it meaningful, the additional stations should be established as a high priority within Environment Canada.

Hydraulic information exists on watercourses in Canada wherever there is a hydrometric station. This information is useful for evaluating instream resource needs, however, it has several drawbacks.

The first problem is that only one cross-section is taken at each hydrometric station, and the hydrometric stations are often spaced very far apart on any one river system. Therefore, the use of these single transects for fully describing the actual channel morphology of a river system is limited.

Second, the cross-section taken at gauging stations is also somewhat atypical of the average river course cross-section in that the stations are located in relatively narrow, uniform flow locations to make the gathering of the hydrology data more accurate. Therefore, from an instream resource point of view, these cross-sections have value only for evaluating instream flows at the planning level.

It is necessary, therefore, that cross-sections of typical stream habitat areas be run on a regular basis in Canada to enable the use of this data for establishing accurate and equitable water use allocation where multiple use is necessary. Cross-section data should be collected on a regular basis at least for a few years, since stream channel morphology changes with time.

Data gathering to provide the necessary input for the third component of the process necessary to establish instream resource needs is probably the most difficult, time-consuming, and expensive. As stated previously, this is particularly true of biological resources. Two types of data are necessary to establish the needs of biological instream resources. The first is to establish species presence and relative abundance in different regions of a watercourse. The second data requirement is to numerically describe how these resources use the habitat in these reaches.

The gathering of species abundance information has been going on in Canada to some extent in the past, however, much more information is usually required in any particular watercourse when water use planning and allocation is considered. The numerical description of how these resources, particularly fish resources, use habitat in flowing systems is a new area of scientific documentation and very little good information is available on this subject in Canada. The objective of such studies would be to measure the water depths, velocities, substrate type, temperatures, water quality, cover type, etc. that fish and wildlife presently are experiencing in a watercourse and to establish, by the concentration of relative numbers, the presumed preference of the different life stages for the different habitat parameters. Much more information is required for this particular component to enable assessment of instream resource needs and subsequently determine water use allocation.

5.0 REFINING NATIONAL STANDARDS APPROACH TO EFFLUENT BY MAKING STANDARDS HIGHER IN INSTREAM RESOURCE SENSITIVE AREAS

As discussed in previous sections, there is generally enough legislation presently on the record in Canada to manage water quality concerns in watercourses. However, one area where the national effluent standards and more local water quality standards do not seem adequate to properly protect instream values is in locations where multiple industrial and municipal pollution loadings occur. In these areas or in other areas where particularly sensitive values are present, effluent standards which are higher than the national standards are necessary.

Federal pollution control agencies claim that higher standards are applied in such areas which is, in fact, correct in some cases. However, more specific standards for multiple pollution and high instream resources value situations are necessary in Canada. These higher standards could then be administered by the river basin management boards.

VI RESTORATION AND ENHANCEMENT OF INSTREAM RESOURCE VALUES

1.0 REVIEW OF WATER ALLOCATIONS

Water rights awards and water development facility licencing is done in Canada on a permanent basis. No provision is made for review of these water use allocations in light of changing technology and society values. This may have been suitable when water resources were plentiful and conflicts were few among water resource users. However, in the future, such water allocations and the facilities for managing them should be regularly reviewed to ensure that new society values, particularly as regarding instream resources, and new water management optimization knowledge and technology can be incorporated into water use schemes. This could be done by revisions in the way the following water allocation mechanisms are applied.

1.1 Water Rights

Water rights in Canada are treated as property rights, and as such, are not normally subject to revision to take into account future demands and better ways of using the water system. However, even property rights in Canada can be expropriated in the general public interest, and since many water rights in Canada are held by government or crown corporation bodies to produce hydroelectric power, potable water supplies and irrigation water, it seems that it would be appropriate to examine many past water rights and to set up a mechanism for awarding future ones that is perhaps more flexible than the present system.

It is not suggested that water rights be subject to year-to-year whims of public pressure groups or short-term interest of government. However, a regular review of water rights awards, every 10 or 15 years, to ensure that water is being used to the maximum benefit of society, would seem appropriate. This, in fact, is being done in many U.S. jurisdictions and water rights conditions are being revised to provide greater benefit to instream resources in these jurisdictions.

1.2 Water Use Facility Re-licencing

Licences for hydroelectric dams, potable water supply facilities and irrigation schemes presently are issued on a very long-term or permanent basis in most jurisdictions in Canada. In the U.S., such facilities must go through re-licencing procedures every 5 to 10 years to ensure they are in compliance with the conditions of the licence, to allow the public to comment on how the licence might be changed to benefit the public interest, and to allow appropriate government agencies to review factors such as facility safety, health standards and operation procedures. This would seem a worthwhile procedure to develop for Canada in that it again allows new benefits for instream and other water resource users to accrue from changes in previous operations which were considered acceptable in their day.

1.3 Preparation of Water Use Plans

Canadian water management agencies and water use agencies tend to operate in a very low profile, sometimes secretive manner, regarding their use and future intentions for use of water related to their particular development. One way of getting around this problem and allowing the public to be made more aware of what water use agencies have planned for the future, is to have such agencies file water use plans for each of their facilities every five years or some appropriate time period. These plans can be formulated according to a certain format, as set out by water management agencies, and would contain information which could then be put to a relatively short, succinct public hearing process, between the draft stage of the plan and the final stage, to ensure public interests are taken into account. Once such water use plans are formulated for a particular period, when the date of their validity is up, the plan could be updated for the next five-year period, and the water resource management agency can make a decision, based on the plans in the update, whether or not to hold public hearings on the proposed changes.

2.0 INCREASE IN INSTREAM RESOURCES FAUNA NUMBERS

2.1 More Restricted Resource Use Management

A common cause of low fish and wildlife numbers in instream habitats is that they have been overexploited in the fisheries and hunting activities which make use of these resources. One of the most pressing instream resource management needs in Canada, particularly near major population centres and other areas which are being heavily fished and hunted, is to decrease the resource harvesting effort, and therefore the numbers of fish and wildlife being captured and harvested. This is not a difficult technical problem, but takes considerable political will and management determination.

2.2 Establishment of Resource Propagation Facilities

The technology for restoring and enhancing instream fisheries and wildlife values through increasing the numbers of the fauna produced is well advanced. Large enhancement programs are underway to increase the value of these resources in the streams and rivers in Canada. This is particularly well developed on the Pacific coast for salmonid fish species. There is a need for much more research in this field to look into the possibilities of expanding this technology to many other fish and wildlife species in Canada, particularly in more northern regions. There is no apparent technical reason why very large benefits cannot be achieved to society by a judicious management of fish and wildlife propagation facilities in the future to allow a larger human population to increase the overall exploitation of these resources.

3.0 PHYSICAL CHANNEL MODIFICATIONS

3.1 Navigation

Navigable waterways are being dredged and improved regularly in Canada. The benefits of this activity to waterborne transportation are obvious and no further discussion of them is required in this report.

3.2 Fisheries

Channels can also be physically altered to make them much more productive for fish resources. The systems suitable for this kind of restoration and enhancement are generally smaller than the ones used for navigation enhancement. Many techniques for removing migration blockages, redesigning stream channels to have more suitable pool-riffle sequences, and placing suitable substrate material exist. Details are outlined in the Salmonid Enhancement Guide (Fisheries and Oceans Canada 1980).

3.3 Wildlife, Recreational Boating and Water Sports, and Aesthetic Values

Other types of stream channel modifications can be made to make watercourses more attractive to wildlife, recreational activities, and for aesthetic viewing. Many examples of these types of modifications can be seen in Canada's parks and green strip areas in cities. Development of such modifications are now necessary skills in the disciplines of park planning and landscape architecture. Instream wildlife enhancement managers have developed techniques for waterfowl which have a high level of success, predictability and aesthetic attractiveness. These enhancement measures are applied by organizations such as Ducks Unlimited, the Canadian Wildlife Service and many provincial wildlife managment agencies.

In some cases, physical channel modifications of watercourses for the above instream values can have impacts on other instream resources such as fish as described in section III. Instream resource development priorities must be established on systems having multiple potential instream water uses.

4.0 WATER FLOW MODIFICATION

Wildlife, recreational boating, water sports, navigation and particularly fish resources can benefit significantly from water flow modification schemes which are designed properly to improve habitat and activity needs of these resources. The following is an outline of some of the benefits which accrue from a properly managed water flow modification scheme.

4.1 Fisheries

Fish resources in Canada have extremes in water flow to contend with which considerably reduces the production potential of many watercourses in which fish resources are located. In areas of Canada where freezing takes place in winter, fish resources are often severely limited by few overwintering areas where they can find free water under the ice. Other areas of Canada experience very low flows in winter, in summer, or periodically throughout the year. These low flows can cause migration blockages, loss of eggs spawned in areas which become dry, anoxic or too warm water quality conditions, and reduction in rearing area habitat. Flows which are managed to increase the low flow levels in river systems during these times can thus considerably increase the fish productivity of the systems.

Extreme and even moderate flood flows on many watercourses can destroy fish feeding habitat, wash juvenile fish from rearing areas, and cause severe scouring or siltation of spawning beds. A properly managed change in these extreme flows to more moderate levels can again have significant benefits to fish.

Given sufficient motivation and imagination, water resource managers and the proponents of water development schemes can often accommodate the flow changes necessary to restore and enhance fish resources in their overall economics and engineering of a project. Much of the present techniques for fisheries enhancement are based on water flow manipulation. In Canada, with approximately one-fifth of the earth's water resources, the potential for increasing these instream biological resources through imaginative water management projects is enormous.

4.2 Other Instream Resources

On a case-by-case basis, other stream flow modifications can be made in a watercourse to benefit navigation, wildlife resources, recreational boating and sports, and aesthetics. The same instream methodologies for determining flow needs for fish can be adapted for determining these other instream flow resource use needs as outlined in section IV, subsection 3.0.

VII CONCLUSIONS

1. There is a general consensus in Canada that, with some geographic exceptions, there is enough existing legislation presently in place to properly manage water quality aspects of instream resources habitat. Exotic chemical contamination problems could require further control legislation in future.

2. Federal water quantity management legislation, however, is not adequate.

3. The main problem with existing water quality legislation is its administration rather than content. Provisions are often not applied firmly, nor carried out consistently. With a strong level of political and bureaucratic will, most water quality problems can be solved in Canada with the present level of scientific knowledge and technology.

4. Physical instream resources habitat protection is best handled by provincial agencies, except in those provinces where direct federal jurisdiction exists over anadromous species, such as British Columbia and the Maritimes. This is in fact how physical habitat protection is implemented at present.

5. There are large areas of overlap between federal and provincial water quality protection agencies and staff. Most direct water quality management in Canada now is done by provincial agencies and territorial water boards.

6. Detailed water quantity management administrative mechanisms are deficient or almost non-existent in Canada at present.

7. There is a general lack of good scientific information on the relationship of fish and wildlife habitat to instream flows, although at very low flows and very high flows, it is known that fish habitat is affected adversely.

8. A program involving the use of agreed-upon methodologies for establishing flow levels which are necessary to maintain and perhaps optimize biological populations has not evolved in Canada to date. The process of setting instream flows has been a rather ad hoc one in Canada to date.

9. It is recognized by most participants in instream flow regime setting exercises that no methodology will cover all geographic, social or political situations. However, it is also recognized that some reasonably objective methodology is useful to establish proposed flow figures for negotiation among agencies responsible for water allocation, use and instream resource protection. During these negotiations, the methodology can be modified and flow figures suitably changed to reflect local conditions.

10. The Montana method and IFG-4-based methodologies have been the most widely used and accepted methods in the United States for establishing flow regimes.

11. Flow requirements other than flows for instream habitat, such as any necessary flushing flow, flow spikes for stimulating fish migration and higher flows for limiting anchor ice formation and for creating conditions for other instream uses, including river rafting, canoeing, kayaking and aesthetic enjoyment, dictate that flow regimes be established that, at times, may be different from the normal requirements of biological instream resources.

12. Biological utilization index curves used in the full field IFG-4 methodology must be developed for each stream system being analyzed, not derived from the literature.

13. Biological potential or actual standing crop in a stream system cannot be directly calculated from weighted usable area values derived from the IFG-4 method. This methodology only calculates relative habitat area values.

14. Physical habitat estimates must be calibrated by comparing the habitat which was calculated to have been available historically, with biological information for the same period. Hydrology is necessary for such a comparison. Curves of physical habitat based solely on hydraulics do not contain enough information for proper interpretation of IFG results or for evaluation of water management plans. Instream flow establishment methods which do not facilitate this comparison between biological and physical parameters, or which do not lead to a time series comparison, are not as useful for setting instream flows as those that do.

15. Effects of commercial, sports and domestic use of instream biological resources on standing crops must be taken into account when determining the limiting biological criteria to be used in the IFG-4 methodology.

16. To the extent possible, daily hydrographs and hydrological information should be used when evaluating impacts of changed flow regimes on instream resources. Monthly averages can be used for planning purposes if daily flows are not available. Flow regimes established using monthly averages or yearly probability-of-flow curves should be closely doublechecked by using daily flows when these become available.

APPENDIX I A TABULAR SUMMARY OF INSTREAM FLOW NEED METHODOLOGIES

Table 1 Comparison of key features of 19 instream flow need (IFN) methodologies.

Table 1. Comparison of key features of 19 instream flow need (IFN) methodologies. References are referred to by letters corresponding to the citations listed at the end of the table. Basis for method groupings given in text.

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References[1]
GROUP I						
Montana Method Tennant (1976)	Tennant (1976) Utah Division Wildlife Resources (Geer 1980) (also other agencies)	Hydrology-based IFN protection set as % annual average discharge All stream sizes, all species	Historic flow record, visual assessment, & photographic record Expert judgement (Bill Geer, pers. comm.)	General application Quick Inexpensive Moderate field expertise	Does not quantify effects of specific discharge change Overlooks short-term discharge influences and implications of constant flow	b,c,d, f,n.
Northern Great Plains Resources Program Dougal (1979) Anon (1974)	Wyoming	Hydrology based: 20-yr. flow duration curves Determines monthly IFN protection flows	Long-term flow records Hydrologist Biologist (judgement)	General application Quick Inexpensive: no field work required Adjusts flow data to mask abnormal events, eg. spring peaks are broadened, apparent duration extended	Requires 20 yrs. of record May not provide IFN at very low flows	c,f,h
Hoppe Method Hoppe (1975)	Hoppe and Finnel (1979): US Bureau of Sports Fisheries & Wildlife, Alberquerque, New Mexico	Hydrology-based: uses percentile exceedance values on flow duration curves to determine spawning, cover & flushing flows All streams, all species	20-yr. flow record Biologist (judgement)	General application Quick, inexpensive: no field work	Requires 20 yrs. of record Slow (therefore costly) without computer (HP 65)[2] Rough estimator	c,g,n

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[1] Letters correspond to references listed on the last page.

[2] HP65: The data analysis can be handled by a Hewlett Packard Model 65 programmable calculator.

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
New England Flow Recommendation Policy Method Knapp (1980) U.S. Fish & Wildlife Service (1981)	U.S. Fish & Wildlife Serv., Region 5, Massachusetts	Hydrology-based: determines Aquatic Base Flow (ABF) from Aug. flow record or Constant Yield Factor (CYF) All streams, all species	25-yr. flow record Biologist	General application Quick, expensive: no field work CYF available, 0.015 $m^3/s/km^2$, for systems without 25-yr. record; higher CYF avail. for spawning and incubation	CYF and ABF developed only for New England States	c,i
Utah Water Records Method Geer (1980)	Utah Division of Wildlife Resources (Geer 1980)	Hydrology-based: recommended summer and winter minimum flows = mean for the period of record of the seasonal (6 month) minimum monthly mean flow All streams, all species	Monthly flow data from discharge record or from simulation based on hydraulic and runoff data Biologist	General application No field work (usually) Specifies min. flows for IFN	Does not quantify impacts Requires flow records or large funds for flow record simulation	a
Utah Water Yield Method Geer (1980)	Utah Division of Wildlife Resources (Geer 1980)	Hydrology-based: determines minimum flows for IFN as average normal flows All streams, all species	Monthly flow data from discharge record or from simulation based on hydraulic and runoff data Biologist	General application No field work (usually) Sets protection flows higher than historic min. flows (enhancement)	Does not quantify impacts Requires long-term discharge records, or historic flow simulation, to provide flow data Criticized for specifying flows higher than historic flows	a
One Flow Method Sams and Pearson (1963)	Oregon Fish Commission; Oregon streams	Hydrology-based: relates discharge to habitat conditions determined from aerial photos Determines optimum flow for spawning salmonids All but smallest streams	Discharge data Detailed air photos Spawning criteria Biologist (judgement)	Quick, inexpensive, usually no field work Considers habitat "quantity" (widths)	Does not apply to small streams (not visible on air photos) Does not apply to very low flows Requires high detail air photos; costly to obtain if not available Requires correct spawning criteria	h

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
GROUP II						
R-2 Cross (Colorado Method) Milhous (1978)	Colorado Division of Wildlife	Hydrology related to hydraulics and species' habitat criteria Determines indicator of habitat quantity at unobserved discharges Relies on Manning equation Wadable streams; all species	Hydrology data Cross section data from one transect Biologist (expert judgement) Technician	Ties flows to a representation of hydraulic conditions Can predict habitat quality, therefore can compare effects of different discharges on habitat	Crucial dependence on species criteria, accurate measurements and placement of transect (Eddie Kochman, Colorado Fish, pers. comm) Does not work well on non-wadable streams Subject to error in Manning's n at maximum or minimum discharge	h
GROUP III						
USFS Region 4 Method Bartschi (1976)	USFS; Utah Division of Wildlife Resources (Geer 1980)	Hydrol./hydraul.-relationship Determines a minimum flow = flow at 80% habitat value calculated for a summer low flow Small mountain trout streams; cold water fish	Habitat ratings Manning equation or R-2 cross program Multiple cross-section data Expert biologist Technician	Specific use for small streams Determines a low flow for IFN Considers habitat quality High accuracy	Does not quantify impacts Does not work for large streams and warm water species Does not recommend a flow regime Requires data on low summer flow May require costly field work Requires expert judgement (Geer 1980)	b,d,f,h
Water Surface Profile (WSP) Method U.S. Bureau of Reclamation (Anon 1967)	US Bureau of Reclamation	Hydrol./hydraul. relationship Designed to predict hydraulic parameters below dams and constrictions Predicts depths and velocities longitudinally for different discharges Wadable streams; salmonid species	Discharge record and cross-section data including water surface elevation Biologist Technician (2)	Specific use for small salmonid streams More sophisticated than R-2 cross Can compare habitat at various flows Considers sediment transport factors if required	Does not incorporate species habitat criteria May result in critically low habitat Expensive	b,c,g,h

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
Waters (Calif.) Method Pacific Gas and Electric Company Dept. Eng. Res., and Calif. Dept. Fish and Game (Waters 1976)	Calif. Dept. of Fish and Game (Waters 1976)	Hydraulics-based: Determines an optimum flow for certain life stage activities of salmonids in Calif. streams	300 data points in 12-18 transects at different flows Habitat criteria weighting factors 3-man crew, incl. expert biologist	Applies to natural and altered flow regimes Can employ habitat criteria weighting factors	Costly field work, especially for habitat criteria No hydraulic modelling Does not recommend protection flows Expensive if no computer available	e,f,g
Collings (Washington) Method Collings (1972, 1974)	Washington Dept. of Fisheries; USGS	Hydraulics-based: Determines a preferred flow as the discharge that produces max. habitat; and IFN maintenance flow = flow at 75% max. habitat All streams, all species, spawning and rearing	Min: 4 transects in 6 places for 5 discharges Correct habitat criteria Biologist Technician	Specific use for spawning and rearing Provides 2 flow recommendations: preferred and maintenance	No hydraulic modelling Costly field work for data at different flows Uses binary habitat criteria (upper and lower limits)	c,f,h
Thompson (Oregon) Method Thompson (1977, 1974) Sams and Pearson (1963)	Oregon State Fish Commission	Hydraulics-based: uses usable width and weighted usable width Recommends min. and optimum flows for salmonid life stages	Species composition and temporal use patterns Habitat criteria for weighting factors Cross-section data from representative habitat for target species and activities High-level expertise for habitat quality judgments	Specific use for salmonids Powerful method for specific season and habitat criteria Can incorporate usability weighting factors	No hydraulic modelling Requires expert judgement to place transects Requires costly labour for specific weighting factor data	c,e,f,h

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
Idaho Method Cochnauer (1976)	Idaho Dept. Fish & Game (White, 1975)	Similar to Thompson method; uses WSP program to predict depths and velocities Designed to predict loss of habitat at reduced discharge in non-wadable streams Determines IFN maintenance flows for fish passage, spawning and rearing for warm water species	Cross-section data from critical areas Min. 4 transects Expert judgement (biologist) to select critical areas Correct habitat criteria	Applies to large systems; also works for small streams Reduces field time (over Thompson method) Predicts habitat quantity and specifies flows	Small data base, low reliability Requires expense of boat and related gear for large systems Requires accurate, specific habitat criteria (expensive if not available)	b,f,h
Indicator Species Over-riding Consideration Method Bovee (1976)	North Great Plains Resources Program (untested); K. Bovee, Instream Flow Group, Fort Collins, Colorado	Similar to Thompson or Collings, depending on species or life stage activity Determines flows for optimum and maintenance habitat, for species with narrowest range of tolerances for habitat characteristics	Cross-section data from critical areas Expert judgment (biologist) to identify critical areas, Accurate criteria to select indicator species Accurate habitat criteria	Applies to warm water species in large rivers Requires effort only for one species' requirements Incorporates weighting factors Specifies flows	Requires highly experienced field chief Costly field work to obtain habitat criteria if not available Disregards other species: could jeopardize other species	f,h
GROUP IV						
Water Resources Research Institute Method (WWRI or Wesche Method) Wesche (1976)	Wyoming Game and Fish Commission	Hydrology/cover relationship Designed to assess habitat quantity as a function of cover and discharge Small streams, cover dependent species	Cross-section data, incl. cover, at as many transects as necessary to represent the stream reach Expert judgement re number and placement of transects	Specific use for brown trout in mountain streams High reliability Costs reduced if R-2 Cross or WSP programs used to model hydraulics	Costly labour Does not apply to large streams Does not work for species or life stage not requiring cover	h

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
USFS Region 6 Method Swank (1975)	Swank (1975) US Forest Service, Portland, Ore.	Hydrology/width relationship Determines habitat quantity as function of width and discharge Recommends optimum flow as flow at peak of curve	Cross-section data incl. cover, for min. 3 discharge levels No. of transects as necessary Accurate species criteria	Specifies optimum flow Allows for judgemental selection of minimum maintenance or preservation flows Compares amount of habitat change with change in discharge	No hydraulic modelling Costly field labour Crucial dependence on accurate habitat criteria Requires cover data (Gerry Swank, pers. comm. USFS, Portland)	h
Habitat Quality Rating Nickelson (1976)	Oregon Dept. Fish & Wildlife	Hydrol./hydraul. relationship Determines "the flow which yields the lowest acceptable carrying capacity" Requires water and habitat quality Oregon coho streams	Cross-section data at various discharges Specific, accurate habitat rating criteria Expert judgement (biologist) to place transects	Provides assessment of habitat quality Specifies min. flow Includes cover factor	No hydraulic modelling Expensive Not highly reliable Not tested on other systems	i

Table 1 (cont'd)

Method and Source	Past and Present Users	Rationale and Designed Use	Information and Expertise Requirements	Advantages	Disadvantages	References
Instream Flow Incremental Methodology Main (1978) Bovee (1980) Bovee and Milhous (1978)	US Bureau of Reclamation, Calif. Dept. Water Res; Oregon Dept. Fish and Wild. Utah Division, Wild. Res.	Hydrol./hydraul. relationship, based on discharge record, accurate hydraulic modelling, habitat use (time & species) and habitat weighting factors Designed to assess effects of flow changes on habitat quantity Provides data for flow negotiation	Multiple cross-section data Substantial hydrology record Accurate species composition and distribution data Accurate habitat preference criteria Expert biologist to select reaches and transects	Quantifies effects of flow change on habitat quantity Powerful tool Widely recognized Quantifies wetted area in terms of its usability as habitat Compares well with HQI method for small streams	Must be calibrated to individual stream hydraulics High labour cost Computer or access required Not designed to determine IFN for natural systems Gives equal weight to each hab. param. (Lincoln Pearson, pers. comm., Oregon Fish & Wildlife) Requires judgement to ensure sensible depth and velocity calculated for each IFG4 cell Disagrees with HQI on large rivers (Eddie Kochmann, pers. comm.)	b,c,d, f,g,h

References

Letters in the references column correspond to the following citations. Full references are included in Appendix III, Bibliography

a	Geer (1980)
b	Horton and Cochnauer (1980)
c	Loar and Sale (1981)
d	Nelson (1980)
e	Neuman and Newcombe (1977)
f	Ott and Tarbox (1977)
g	Prewitt and Carlson (1977)
h	Wesche and Rechard (1980)
i	US Fish and Wildlife Service (1981)

APPENDIX II

1.0 REVIEW OF PERTINENT CANADIAN FEDERAL INSTREAM RESOURCES MANAGEMENT LEGISLATION

1.1 Review of Fisheries Act

Sections related to water quantity management include the following:

1. Section 20 concerns the construction of fishways where streams are to be obstructed (e.g. as by a dam), so as to block the passage of fish. The fishway must meet the approval of the Minister. Where such a fishway is not feasible, the owner of the obstruction must pay for the construction, operation and maintenance of a fish hatchery sufficient for the requirements of the migrating fish (Subsection 20(1)).

   Approval for a fishway is required before construction of the obstruction. Any adjustments or changes necessary after the operation is begun are to be paid for by the owner of the obstruction (Subsection 20(2)).

   The fishway must be maintained by the owner to continue to satisfactorily provide for fish using the waters (Subsection 20(3)).

   Where the Minister authorizes payment of one-half of the cost of the fishway construction, and the fishway proves to be ineffective, the costs of changing the fishway will be paid for by the Crown (Subsection 20(4)).

   If necessary, the Minister may authorize the construction of a fishway where the owner did not comply with the Act, and collect the costs from the owner (Subsection 20(5)).

   Where the structure is no longer used, the owner is to remove it, or, if not, the Minister will have it removed at the owner's expense (Subsection 20(6)).

The owner may be required to install mechanisms to prevent damage to fish by the obstruction, or to assist the ascent of the fish (Subsection 20(7)).

Flow of water must be maintained sufficiently to allow passage of fish during their descent (Subsection 20(8)).

Passage of fish must not be impeded while the obstruction is being assembled (Subsection 20(9)).

Sufficient flow of water must be released below the obstruction while it is being assembled (Subsection 20(10)).

2. Section 53 prohibits any undue obstruction to fish passage, and provides for the Minister to order such obstruction removed.

3. Section 28 requires the use of a fish guard or screen to prevent the passage of fish from fisheries water into a system used to conduct water for irrigation, manufacturing, power generation, domestic or other purposes, the mesh or hole size of which is subject to the Minister's approval and inspection, and the maintenance of which is to be the responsibility of the owner of the water conductor.

4. Section 31 prohibits, and describes the penalties for, conducting any work which causes damage to fish habitat.

Subsection 31(1) states, "No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."

"Fish habitat" is defined as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes" (Subsection 31(5)).

Subsection 31(2) allows for any work which may damage fish habitat to be done according to "conditions authorized by the Minister or under regulations made...under this Act".

5. Section 33 prohibits the depositing of deleterious substances into fish habitat.

The following regulations and guidelines related to fish habitat management and protection in shore zones have been promulgated under the Fisheries Act:

1. Chlor-Alkali Mercury Regulations
2. Fish Processing Operations Liquid Effluent Guidelines
3. Metal Mining Liquid Effluent Regulations and Guidelines
4. Penalties and Forfeitures Proceeds Regulations
5. Petroleum Refinery Effluent Regulations and Guidelines
6. Pulp and Paper Effluent Regulations
7. Guidelines for the Pulp and Paper Effluent Regulations
8. Yukon Territory Gravel Removal Order.

Jurisdiction of the Fisheries Act relates to "Canadian fisheries waters" which are "all waters in the fishing zones of Canada, all areas in the territorial sea of Canada and all internal waters of Canada" (Section 2). Sections 35 and 36 specify the powers of fishery officers, peace officers, and fishery guardians. A place where an officer believes there is evidence of contravention of the Act may be entered by the officer. A person an officer believes to have committed, is committing, or will commit, an offence, may be arrested by the officer. Parts of some sections of other federal legislation takes precedence over the provisions of the Act (e.g. Subsection 33.2(7) gives precedence to an order of a pollution prevention officer under the Canada Shipping Act, over any "inconsistent" requirement or direction of an inspector).

The administration of the Fisheries Act is the responsibility of different agencies across the country. In British Columbia, marine waters and freshwaters inhabited by salmon, the Act is administered by Fisheries and Oceans Canada and the Environmental Protection Service of Environment Canada. Steelhead trout and non-salmon waters in the province are the responsibility of the British Columbia Ministry of Environment Fisheries Section.

In Alberta, Saskatchewan, Manitoba, Ontario and Quebec, administration of the Act has been delegated to the province. In the maritime provinces, Newfoundland and Labrador, the Yukon and Northwest Territories, the administration of the Act is carried out directly by Fisheries and Oceans Canada and the Environmental Protection Service of Environment Canada.

Use of the Act for protection varies widely across Canada. For example, British Columbia generally has more prosecutions under the Act than the rest of the country combined. All provinces and two territories have passed legislation which applies to the management of fish habitat in their jurisdiction. In some provinces, the Fisheries Act is not used at all as a tool for fish habitat management.

1.2 Review of Other Federal Legislation Relating to Instream Resource Protection

For the following Acts, the federal government body administering the Act is indicated in brackets.

1. Ocean Dumping Control Act

"An Act to provide for the control of dumping of waste and other substances in the ocean", with which estuaries are contiguous.

The Act prohibits ocean dumping except under conditions specified in a permit (Subsection 4(1)), and pertains to any structure in the area of the sea to which the Act applies (Subsection 4(2)).

Dumping is defined as "any deliberate disposal from ships, aircraft, platforms or other man-made structures at sea of any substance", except for substances arising from the "normal operations of" such a vessel, or from the "offshore processing of seabed mineral resources" (Subsection 2(1)).

2. Canada Shipping Act (Ministry of Transportation)

The Act provides for the Governor in Council to make regulations to prohibit the discharge from ships of any pollutants, which are defined as:

"a) any substance that, if added to any waters, would degrade or alter or form part of a process of degradation of alteration of the quality of those waters to an extent that is detrimental to their use by man or by any animal, fish or plant that is useful to man, and

b) any water that contains a substance in such a quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any waters, degrade or alter or form part of a process of degradation or alteration of the quality of those waters to an extent that is detrimental to their use by man or by any animal, fish or plant that is useful to man..."

(from a quotation in Savage, R.K., and LG. Morrison. 1977. A digest of environmental protection legislation in Canada.)

3. Arctic Waters Pollution Prevention Act (Indian Affairs and Northern Development)

"An Act to protect pollution of areas of the Arctic waters adjacent to the mainland and islands of the Canadian Arctic."

Section 4 prohibits any person from depositing any waste in Arctic waters or in any place were the waste may enter Arctic waters, except in waters which lie within a water quality management area designated pursuant to the Canada Water Act, and if the waste and the deposit of the waste is in accordance with regulations provided for in Section 16 of that Act.

4. Northern Inland Waters Act (Indian Affairs and Northern Development)

"An Act respecting inland water resources in the Yukon Territory and Northwest Territories".

The Act requires that a licence be obtained by anyone wishing to cause a diversion of a waterbody within a water management area (Subsection 3(2) and Section 4). The Act prohibits the release of any waste into any waters. Waste also should not be left where it may enter any waters (Section 6). A licence, however, may be obtained in which conditions may be prescribed to allow such deposit of waste.

5. Navigable Waters Protection Act (Ministry of Transport)

"An Act respecting the protection of navigable waters."

Part I generally prohibits unauthorized construction or activity which may interfere with navigation. Authorization may be obtained from the Ministry of Transport (Subsection 5(1)).

Part II concerns sunken or grounded vessels, the position of which must be reported and marked. Removal is to begin immediately.

Part III (the last) provides for regulations relating to ferry and bridge construction and navigational signals.

6. Canada Water Act (Environment Canada)

"An Act to provide for the management of the water resources of Canada including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources."

The Act is written in four Parts: Part I, Comprehensive Water Resource Management; Part II, Water Quality Management; Part III, Nutrients; and Part IV, General.

Part II is most pertinent, providing for a prohibition on the deposit of waste in any waters of a water quality management area. Section II provides for the incorporation of federal water quality management agencies to conduct water quality management programs.

7. International Boundary Waters Treaty Act (External Affairs)

The Act adopts the 1909 International Boundary Waters Treaty. It applies to lakes and rivers which lie across the Canada-United States boundary. Saltwater bodies are not included.

The treaty provides for the establishment of the International Joint Commission, one of the functions of which is to participate in the approval of "construction or maintenance of any obstruction or diversion of boundary waters which affects the waters' natural level or flow" (Article VII). The treaty also states that rivers and lakes lying across the border "shall not be polluted on either side to the injury of health or property on the other" (Article IV).

8. Environmental Contaminants Act (Environment Canada, Health and Welfare Canada)

The Act provides for the control of substances which, by entering the environment, may "constitute a significant danger to human health or the environment" (Subsection 4(1)). The manufacture, importation, or use of such substances must be made known to the Minister (Sections 4 and 6). Inspectors may be appointed to examine such products, to determine their compliance with the Act (Sections 9, 10 and 11). The Act prohibits release of such substances into the environment (Subsection 8(1)), and restricts the use of such substances in production processes (Subsections 8(2) and 8(3)). Contravention of Section 8 of this Act may result, on summary conviction, in a fine of as much as one hundred thousand dollars, or on conviction upon indictment, in "imprisonment for two years" (Subsection 8(5)).

9. Pest Control Products Act (Agriculture Canada)

The Act prohibits handling any pest control product "under unsafe conditions" (Subsection 3(1)), and requires that any such product must "conform to prescribed standards", and be "registered...packaged and labelled as prescribed" (Subsection 4(1)). The term "control product" refers to mechanical and chemical methods of affecting pests, and includes substances that are used in the production of control products.

The Act provides for the Minister to appoint inspectors who may enter premises where control products are being made or stored, etc. (Subsection 7(1)), and may "seize or detain" any substance which is not being properly handled (Subsection 9(1)).

Issued under the Act are the Pest Control Products Regulations (S.O.R./72-451).

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APPENDIX IV

TERMS OF REFERENCE

The objectives of the contract are:

To identify the water requirements (quantitative and qualitative) of various instream uses, and their values; and to recommend appropriate means for their protection against conflicting resource developments.

The contractor hereby agrees to:

1. Describe the full range of instream resource uses in Canada and their flow, depth and quality requirements;
2. Develop methodology to assess the values of instream resource uses;
3. Analyze current conflicts among instream uses and between instream and other water and land uses, providing regional examples;
4. Assess existing laws, regulations, and procedures for the protection of the aquatic environment, and recommend federal policy changes as appropriate to protect, restore and enhance instream resource values.